METHODS AND COSTS OF SHAFT SINKING IN THE COEUR D'ALENE DISTRICT, SHOSHONE COUNTY, IDAHO

By John R. McWilliams and Eric G. Erickson

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METHODS AND COSTS OF SHAFT SINKING IN THE COEUR D'ALENE DISTRICT, SHOSHONE COUNTY, IDAHO[1]

by

John R. McWilliams[2] and Eric G. Erickson[3]

INTRODUCTION AND SUMMARY

The technological and economic pattern of the U. S. mining industry has undergone a rapid and continuing change since World War II. To provide realistic up-to-date cost data and to disseminate knowledge of technical developments, the Federal Bureau of Mines, with the cooperation of individual mining companies, is presenting a series of mining methods and costs reports similar to those it issued before 1939.

Shaft sinking has always played an important part in mine development and operation and is an appropriate subject for this series of reports. Shafts are especially important in areas such as the Coeur d'Alene district of Idaho, where every major mine is served by one or more shafts and shaft sinking is in progress at one mine or another almost continuously.

This report is based upon data and information made available by several Coeur d'Alene operators who have completed shaft-sinking projects recently. The first section contains a general description of shaft-sinking practices in the district. The second section describes in more detail methods and procedures employed in 13 shaft-sinking projects at 10 mines. These projects include 2 new shafts collared underground, 1 new shaft collared on the surface, and the deepening of 10 existing shafts. The shaft projects ranged in size from two to four compartments and from 160 to 2,083 feet in depth. Both hand- and machine-shoveled shafts were represented. Sinking costs ranged from $135.86 to $228.84 per linear foot, or from $0.92 to $2.02 per cubic foot. Labor costs averaged $0.88 per cubic foot, including $0.51 for direct on-the-bottom labor. Average total cost for hand-shoveled shafts was $1.30 per cubic foot, compared with $1.21 for machine-shoveled shafts.

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Original from THE OHIO STATE UNIVERSITY

The Bunker Hill Co., Day Mines, Inc., Hecla Mining Co., Lucky Friday Mining Co., Sidney Mining Co., and Sunshine Mining Co.

Special acknowledgments are due to the participants in the Symposium on Shaft Sinking sponsored by the Northwest Mining Association at Spokane, Wash., Dec. 7, 1957. Much of the material presented at the Symposium is repeated herein. Panel members included Malcom C. Brown, president, Sidney Mining Co.; William H. Love, manager, Hecla Mining Co.; Charles A. McKinley, manager, Sidney Mining Co.; E. B. Olds, superintendent of mines, The Bunker Hill Co.; and Troy M. Tower, mine superintendent, American Smelting and Refining Co.

HISTORY

Lode mining in the Coeur d'Alene district started in 1884 and 1885 with the discovery of lead-silver deposits and the location of claims which were later developed into several well-known mines, including the Morning, Bunker Hill, and Sullivan. Following these initial discoveries, the area was thoroughly explored by an influx of prospectors from the nearby Murray gold fields. In 1890 rail haulage became available, and it was no longer necessary to freight high-grade ore by pack train to railheads at Spokane, Wash. and Missoula, Mont. From 1890 to 1895 severe labor troubles, culminating in martial law, plagued the district. By 1900 the labor unrest was settled, the mines were operating and successful, most of the productive surface lodes had been located, and the camps were well established.

As the high-grade galena ores of the discovery days were exhausted, the major mines installed gravity mills to remove siderite gangue. About 1910 the first commercially successful flotation process in the United States was installed at the Morning mill to recover zinc from siderite tailings (4).[4] By 1918 flotation was an integral part of milling practice in the district. About the same time the Bunker Hill and Sullivan smelter at Kellogg was completed to provide a local market for lead and zinc concentrates, which formerly had been shipped to smelters in Montana, Washington, and California.

Although the district is best known for its lead-zinc-silver production, it is also a ranking copper producer. Copper minerals were identified in the lead-silver deposits as early as 1884, but it was not until 1904 that efforts were made to recover the copper.

The Coeur d'Alene mining district is one of the few districts in the world which has produced over $1 billion of mineral wealth. A total of 420,657 ounces of gold, 572,295,521 ounces of silver, 88,532 short tons of copper, 6,316,326 short tons of lead, and 1,945,172 short tons of zinc was produced between 1884 and 1957. The total value of the recovered metals is $1,703,195,505. The district contains the first, third, and fifth largest lead mines in the United States and the largest silver mine in the world. It ranks 1st in silver production, 2nd in lead production, 4th in zinc production, and 21st in copper production in the United States.

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[4] Underlined numbers in parentheses refer to items in the bibliography at the end of this report. They are listed chronologically.

LOCATION

The Coeur d'Alene mining district, Shoshone County, Idaho, occupies an area of about 400 square miles in the extreme northern portion of the State, about 80 miles east of Spokane, Wash. (fig. 1).

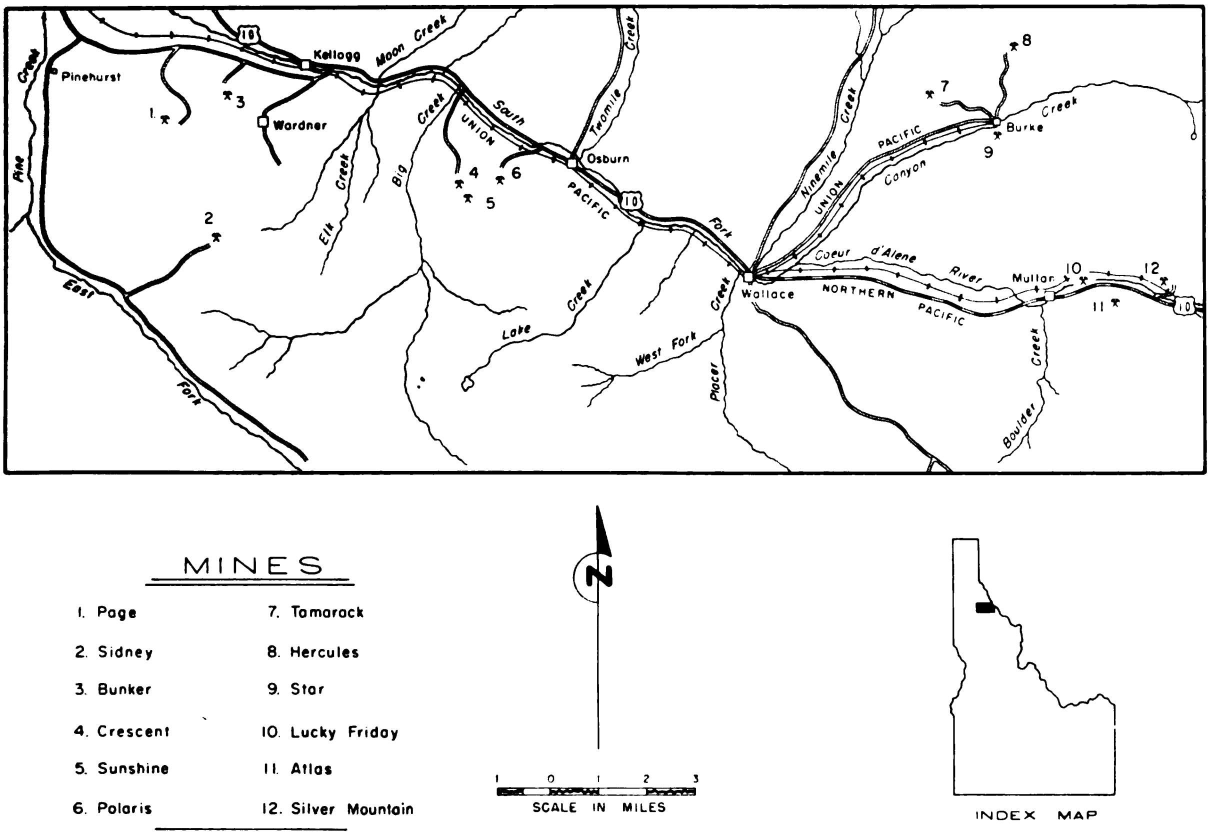

FIGURE 1. - Coeur d'Alene Mining District, Shoshone County, Idaho.

Kellogg (population 4,913) and Wallace (population 3,140), the county seat, are the largest towns and major supply points. The area is traversed east-west by U. S. Highway No. 10 and by branch lines of the Union Pacific and Northern Pacific Railroads. Secondary roads lead up most of the main canyons and are joined by mine access roads.

Topographically, the district is rugged. Except for the mile-wide valley in which Kellogg is located, it is characterized by narrow canyons and steep hillsides. Elevations range from 2,300 feet to 6,295 feet. Annual precipitation amounts to about 35 inches, a large part of which falls as snow during the winter months. The mean daily temperature is 46.1° F.

GEOLOGY (2, 3, 5)

Ore deposits in the district are found almost exclusively in the pre-Cambrian Belt series of metamorphosed shallow-water sediments, which have widespread exposure from western Montana through northern Idaho to eastern Washington and north into Canada.

Within the district (fig. 2), the Belt series has been divided into six formations: Prichard, Burke, Revett, St. Regis, Wallace, and Striped Peak. Rock types include slate, argillite, quartzite, calcareous shales, and many rocks of intermediate composition. Igneous rocks include stocklike intrusions of monzonite and syenite, thought to be outliers of the Idaho batholith and perhaps the source of mineralizing solutions, and local dikes composed of diabase, diorite, and lamprophyres.

The metamorphic rocks have been complexly folded and extensively faulted. The major structural feature is the east-west trending unmineralized Osburn fault, which nearly bisects the district and has been traced for more than 100 miles. It is a normal fault with a relative horizontal displacement of about 12 miles and unknown vertical displacement. South of the Osburn fault are several parallel faults of lesser extent but greater economic significance,

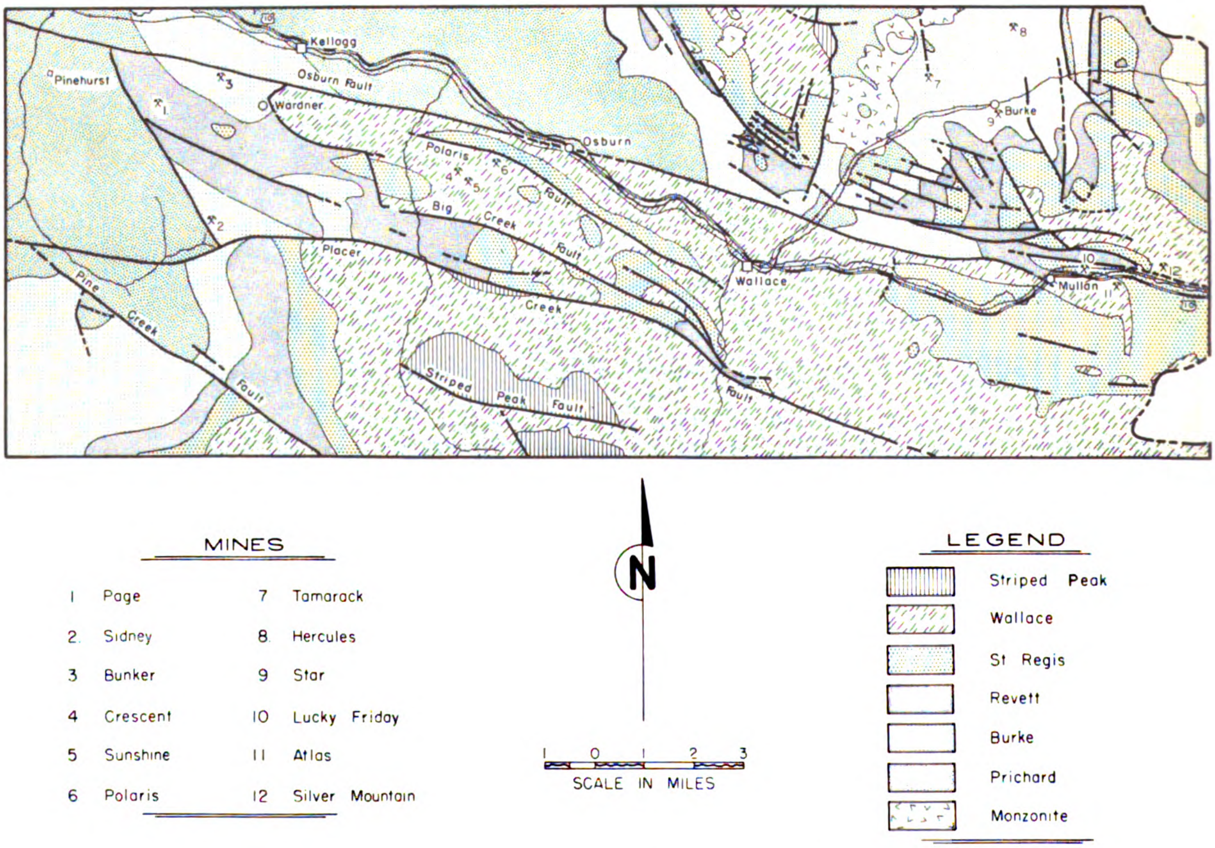

FIGURE 2. - Generalized Geology of the Coeur d'Alene District.

inasmuch as some of the most productive ore zones are associated with them. North of the Osburn fault are numerous faults and crossfaults with strikes trending from north to northwest. These also are mineralized and have produced such mines as the Hecla, Star, and Hercules.

Ore deposits generally are associated with fault zones and may occur as veins occupying fissures or as partial replacements in shear zones. Ore zones are persistent in strike length and depth, but ore bodies within the zones are erratic in occurrence and highly irregular in shape, and many have poorly defined limits. North of the Osburn fault silver-bearing galena is the principal ore mineral, and relatively little sphalerite is present. South of the Osburn fault in the central and east part of the district are silver-antimony-copper deposits containing argentiferous tetrahedrite (freibergite). In the western part of the district, galena and sphalerite are the dominant ore minerals with relatively little silver present. Siderite is the principal gangue mineral and is accompanied by various amounts of quartz, magnetite, and pyrite.

PURPOSE OF SHAFTS

During the early history of the district, adit headings were adequate for the exploration and development of near-surface ore bodies. Later, as the ore zones were found to be persistent laterally and vertically, surface and underground shafts were sunk to explore and mine the ore bodies at ever increasing depths. At the present time every major mine is served by one or more shafts, some of which exceed 4,000 feet in depth and extend to sea level and below.

The shafts included in this report illustrate the major reasons for shaft sinking. Five shafts were sunk considerable distances with the primary purpose of exploring unknown areas, seven were sunk to develop the mine at greater depths, and one was sunk a relatively short distance to prepare a single stope for production.

CHOOSING A SHAFT SITE

Choice of a shaft site is largely dependent upon and limited by the subsurface features which prompted the decision to sink the shaft. Underground sites are chosen to take advantage of existing workings; surface sites are chosen to avoid surface and subsurface drainage patterns and excessive excavation to bedrock. Care is taken to avoid, if possible, unfavorable geologic or other conditions which unnecessarily complicate excavation and maintenance of the shaft. Access to the site and space for waste disposal are also important factors, particularly in the narrow valleys in which many of the Coeur d'Alene mines are located.

SHAFT DESIGN

All shafts in the Coeur d'Alene district are rectangular in cross section and have two or more compartments, depending upon the purpose for which the shaft was designed and the depth to which it extends. Shallow shafts and winzes between several levels usually have only two or two and one-half compartments, the partial compartment serving for a manway and service compartment. In the deeper shafts balanced hoisting is commonly used; hence the minimum number of compartments is generally three—two hoisting compartments and a manway-utility compartment. Still larger shafts may include a separate compartment for hoisting men and supplies in order to free the regular hoist for production.

Most shafts are designed with the compartments alined side by side and with the long horizontal axis of the shaft oriented normal to bedding of the country rock. Experience has shown that such a position is best able to resist rock pressure encountered at depth.

SHAFT-SINKING METHODS

Shaft-sinking methods are usually known by the type of shoveling employed. Until recently, hand shoveling had been the usual practice, but with increases in the cost of labor and a general dislike for hand shoveling by miners, mechanical mucking has all but replaced hand labor. Three types of mechanical shovelers are in common use in the Coeur d'Alene district: Cryderman, Riddell, and Hydromucker. The first utilizes a telescoping boom to which is attached a clamshell bucket; the other two use clamshell buckets suspended by cables from power units anchored to timber above the working face and differ mainly in the manner in which the buckets are positioned and dumped. The Cryderman mucker is adaptable to use in nonvertical shafts, as is shown by its use in the Page shaft, which is inclined at 55°. The Riddell and Hydromucker are used mostly in vertical or near-vertical shafts. All require considerable working space and are less efficient in smaller shafts. A fourth mucker, developed by Hecla Mining Co. to overcome this disadvantage, resembles the Riddell and Hydromucker in working principle, but the clamshell is operated by self-contained air cylinders.

Other than in shoveling, there have been few major changes in methods, though recent innovations, such as the use of rock-bolted bearing sets, prepackaged shaft timber, steel blasting sets, and a self-contained drill car, have contributed to greater efficiency and safety in shaft sinking. Mechanical equipment, including hoists, drills, steel and bits, and ventilation and pumping equipment, has been improved but remains essentially unchanged in principle.

SHAFT-SINKING CYCLE

The shaft-sinking cycle may proceed on one, two, or three shifts per day. On a one-shift basis the same crew performs all the necessary tasks and will complete five rounds in 6 days. On two- or three-shift operations each crew may complete a round, including all supplementary work, or, as is more common, each crew will take up where the other crew left off.

In three-compartment or larger shafts, the sinking crew usually consists of four bottom men, a hoistman, a topman who functions as a nipper, and a part- or full-time motorman in the case of underground shafts. Smaller shafts are usually sunk by a two-man bottom crew, a hoistman, and a topman who acts as nipper and motorman, if necessary.

The shaft-sinking cycle usually comprises three distinct operations—breaking, which includes drilling and blasting, mucking and hoisting, and timbering. In addition there are the supplementary tasks of moving pumps and fans, lowering and blocking the mucking machine if one is used, advancing air, water and ventilation lines, installing shaft guides and dividers if these are not installed during the timbering cycle, and maintaining equipment.

DRILLING

A conventional bench round (figs. 3 and 4) is used almost exclusively. With this method alternate halves of the shaft bottom are drilled and broken in a steplike manner rather than in single lifts as is the case with a full-bottom round. Full-bottom rounds have been used from time to time but have usually been replaced by bench rounds even though the latter require double the amount of time to set up and dismantle drill equipment. Major advantages of the bench round, particularly in wet shafts, are that a sizeable sump is created with no special effort and that a clean, dry drilling face is easily provided. Another advantage is that a bench round tends to "stack" broken rock on alternate sides of the shaft, which not only reduces timber damage from fly rock but facilitates shoveling, particularly when hand shoveling is employed, since most of the broken rock can be scraped into a bucket or pan placed on the low side of the shaft. It is seldom necessary to remove all the muck from a bench round, and usually only the high bench is exposed and cleaned off with compressed air. With a full-face round the entire bottom must be mucked to prepare for drilling.

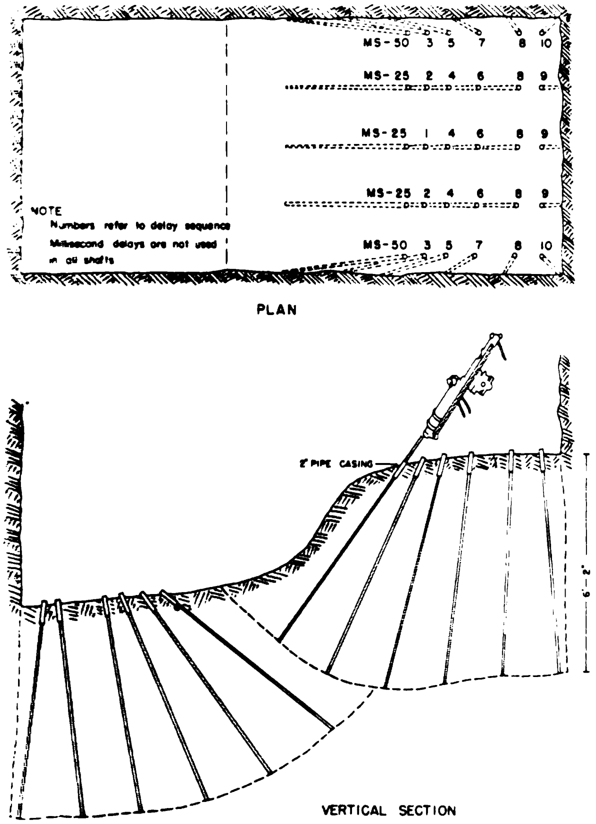

FIGURE 3. - Typical Bench Round in Vertical Shaft (17).

Two types of drills are in common use for shaft sinking, the 55- or 65-pound, hand-held rock drill, and the 3-inch, bar-mounted drifter. The first is known as a sinker and may be either an ordinary rock drill or a drifter converted to a sinker by the removal of the carriage and the addition of handles. In most cases the sinker drill is hand held, but in inclined shafts it may be possible to drill at least some of the holes with the drill mounted on an air leg. Drifters are usually light-weight machines equipped with power-feed carriages and mounted on 3-inch pneumatic bars placed across the short axis of the shaft.

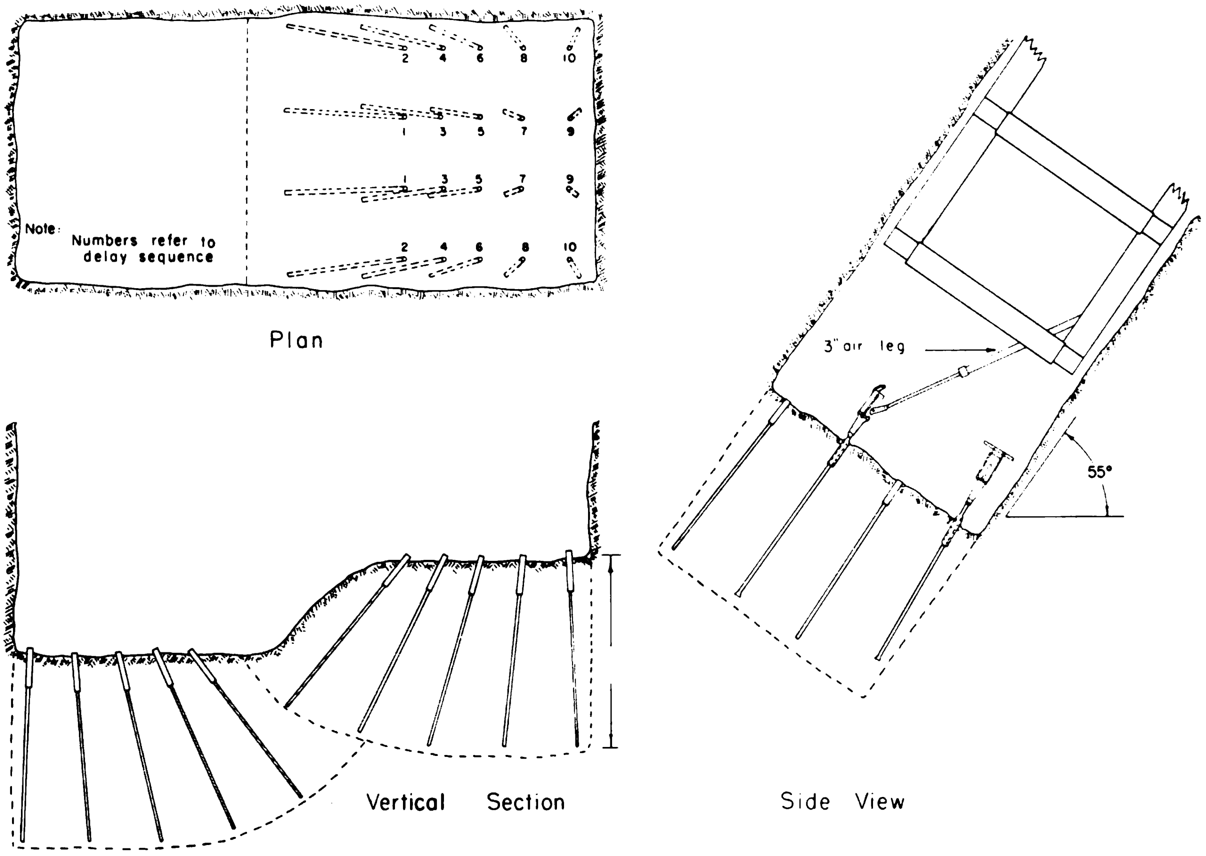

FIGURE 4. - Typical Drill Setup and Hole Pattern for Inclined Shaft.

Advantages and disadvantages of the two drills are as follows: The sinker drill is lighter in weight and more flexible in operation so that a wider range of drill-hole patterns can be used. The bar-mounted drifter is easily adapted to a rectangular shaft, and less physical energy is expended while drilling. Two drifters are usually paired on an air bar, and, except in larger shafts, an entire round can be drilled from one setup. The variety of drill patterns is limited, however.

Sinkers consume less air per foot of hole, and steel breakage is somewhat less than for drifters. Although chisel bits make the sinker useable in fairly hard ground, the efficiency of the drifter increases with the hardness of the ground. In summary, the drifter is preferred in larger shafts and under more difficult drilling conditions; the sinker is favored where light weight and greater mobility are advantageous.

Several drill jumbos have been designed and used for short periods, but none has gained the approval of the shaft miners. A drill car developed and successfully used in the Page shaft incorporated many of the advantages of a jumbo. The car was completely self-contained with built-in air and water manifolds, racks for drill steel, and space for two drills. The drills were permanently connected to the manifolds, and it was a matter of only a few minutes to connect the main air and water lines to the manifolds, unload the drills, and prepare for drilling.

Time consumed in setting up drill equipment ranged from 15 to 33 minutes at the various shafts. The average time was 24 minutes, and there was not a great deal of difference between projects using sinker drills and those using drifters. Time required to tear down or disassemble equipment was about the same as for setting up.

Both carbon and alloy steel are used to about the same extent for drill rods. Round, lugged, 1-1/8-inch, hollow carbon steel drill rods are the most common and are used principally with drifters. Hexagonal steel alloy rods, in either 7/8- or 1-inch diameters are used with some drifters and nearly all sinkers.

The choice of round or hexagonal rods is largely a matter of preference. Both are available in stock sizes and in random lengths. Several of the larger companies have the facilities and prefer to cut and heat-treat their own steel. Smaller companies, or those that do not have heat-treating facilities, usually purchase standard-length drill rods for convenience.

Four-wing detachable bits with tungsten carbide inserts are nearly standard equipment on drifters for use in hard ground. Rods with integral carbide-tipped, four-wing or chisel bits are used with sinker drills. The utility of tungsten carbide-tipped bits is obvious from one example: When the first part of the Star shaft was sunk in 1946 approximately 1.6 feet were drilled with each steel bit compared with 244 feet per carbide bit when the shaft was deepened in 1951-52. Direct bit cost was reduced about 50 percent and total cost, including down time to change bits, was reduced even more. Steel bits are still widely used for collaring drill holes and occasionally are used in softer ground where the more expensive carbide bits are not necessary.

Drilling methods are similar in all the shafts. Holes are usually drilled to solid rock with 2½-inch steel bits and cased with 2-inch pipe. When drifters are used, holes are collared, cased, and continued to depth in one setup. With sinker drills usually all holes in a round are first collared and cased; then each is deepened in rotation for each steel change. From 18 to 36 holes are drilled per round to depths ranging from 5 to 8 feet. Holes actually extend from a few inches to a foot or more below the break line, but because of the difficulty of determining the actual depth, average advance per round is used as the basis for drilling statistics.

Drilling speeds range from 0.20 to 0.89 feet per minute per machine in the various shafts with only a slight edge in favor of drifters. Air pressure ranged from 90 to 110 p.s.i. at most of the sites to 80 p.s.i. or less at sites some distance from the compressors or under unfavorable work loads.

BLASTING

Both 40-percent special gelatin and 45-percent semigelatin dynamites are in general use for shaft sinking, either alone or primed with 60-percent special gelatin. The latter also is used as a booster charge to increase the velocity of lower grade dynamite, or alone, where a greater shattering effect is desired. All the explosives are packed in 1-1/8- by 8-inch paper-wrapped cartridges with 90 to 100 sticks per box for special, and 122 sticks per box for semigelatin, dynamite. Both types have the excellent fume characteristics and good water resistance typical of nitrogelatin explosives. Special gelatin has greater water resistance and is used where conditions are exceptionally wet.

Electric delay blasting caps are in common use and were used at all projects included in this report except one; fuse and caps were used in sinking the Star shaft in 1946-47. Millisecond electric delays are used only occasionally, however, usually to detonate the center or cut holes of a round. The remaining holes are detonated by regular 0 through 10 electric delay caps. The firing sequence shown in figure 3 is typical; the center hole or holes of the row nearest the bench berm are fired first, followed in order by the remaining holes in the first row, center holes in the second row, and so on toward the end wall of the shaft. The regular 110- or 220-volt mine-illumination circuit or a capacitor-type blasting machine is used to provide energy for detonation. Blasting circuits are always pretested by galvanometer.

Powder consumption in this study ranged from 0.11 to 0.29 pound per cubic foot of rock broken and averaged 0.19 pound per cubic foot. The best ratio, and incidentally the widest range, was obtained from 40-percent special gelatin, which ranged from 3.4 to 9.1 cubic feet broken per pound of explosive and averaged 6.0 cubic feet per pound. The lowest ratio was with 60-percent special gelatin, which averaged 4.0 cubic feet per pound. The latter is not surprising, however, since it is used only under exceptionally difficult circumstances. The following table is a summary of performance of the various grades of explosive.

TABLE 1. - Summary of explosive performance

		Strength				
		Special gelatin, 40 percent	Semi-gelatin, 45 percent	Special gelatin, 60 percent	Combined 45 percent and 60 percent	All
Pounds per cubic foot of rock broken.	High...	0.11	0.15	0.25	0.16	
	Low....	.29	.23	.25	.23	
	Average	.17	.18	.25	.19	0.19
Cubic feet of rock per pound of explosive	High...	9.1	6.9	4.0	6.2	
	Low....	3.4	4.4	4.0	4.4	
	Average	6.0	5.7	4.0	5.3	5.5

LOADING

Both hand and mechanical shoveling methods are employed. Hand shoveling is rapidly declining in favor because of the development of satisfactory mechanical methods and the reluctance of skilled shaft miners to work in hand-mucked shafts. Even hand shoveling has improved to a certain extent, inasmuch as muck pans and low-walled buckets, which permit easier shoveling than ordinary sinking buckets, are used to reduce hand labor. Muck pans have a capacity of 8 to 16 cubic feet, and when filled are emptied into the sinking bucket by an air hoist. Hand mucking appears cumbersome, but in actual practice it compares favorably with mechanical methods.

The Riddell mucker (fig. 5) was the first mechanical shaft mucker introduced to the Coeur d'Alene district and remains the most common. Mechanically, the machine consists of a 3/8-yard clamshell bucket suspended by wire rope from a double-drum hoist mounted on a traveling carriage, which is supported several sets above the shaft bottom by a steel frame. Two air hoists and an air motor mounted on the carriage power the entire machine. One hoist operates the clamshell digging line; the other serves the hoist line. The air motor, which is reversible, moves the carriage horizontally in either direction along the tracked steel frame.

In operation one man rides the carriage to operate the clamshell, a second man positions the clamshell on the shaft bottom, and a third man signals the hoist operator. The clamshell is lowered to the shaft bottom, filled, and then hoisted to a height sufficient to clear the sinking-bucket lip. The carriage is then moved to a point directly above the bucket, and the clamshell is dumped. Two or three passes usually are sufficient to fill the sinking bucket, which is then raised, dumped, lowered, and refilled.

The Bucyrus-Erie hydromucker (figs. 6 and 7) resembles the Riddell machine in one major respect: It employs a clamshell bucket suspended by cable from an operating platform several sets above the shaft bottom. The digging action of the clamshell is provided by two single-acting hydraulic rams mounted on the bucket and remotely powered by a hydraulic pump located near the operating platform. A spring-loaded hose reel feeds and retracts the hydraulic line as the clamshell is raised and lowered by a single-drum hoist located on the operating platform. Four men are required for its operation: Two on the bottom to position the clamshell, one to raise and lower the clamshell and operate the hydraulic controls, and a fourth to operate the sinking skip and signal the hoistman.

The hydromucker was used in sinking a three-compartment shaft. A 50-cubic-foot sinking bucket suspended beneath the regular man cage occupied the center compartment, and the clamshell operated in alternate outside compartments. Duplicate hose reels and air hoists were provided in each compartment so that the clamshell could be moved from one to the other merely by disconnecting and reconnecting the hoist cables and hydraulic lines. Two panlike chutes, permanently attached to the sinking skip with hinges, were employed to deflect muck from the clamshell into the sinking bucket.

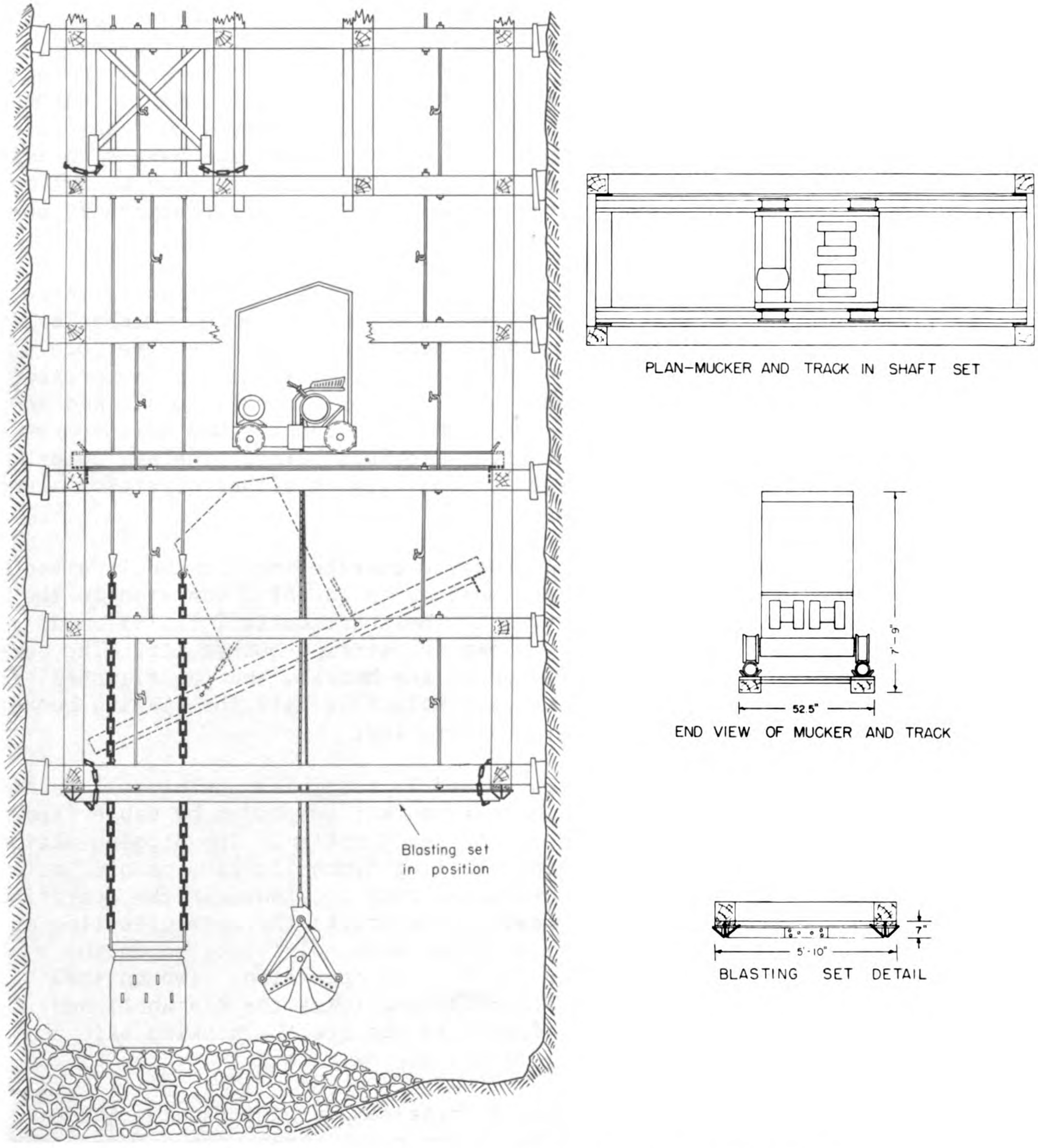
PLAN-MUCKER AND TRACK IN SHAFT SET
7'-9"
52.5"
END VIEW OF MUCKER AND TRACK
Blasting set in position
7"
5'-10"
BLASTING SET DETAIL

FIGURE 5. - Riddell Shaft Mucker and Blasting Set (17).

The Cryderman (figs. 8 and 9) is perhaps the most unusual mechanical shaft mucker to be operated in the district and is the only one which is adaptable to inclined shafts. In appearance and operation it resembles a man's forearm and hand. The forearm is a rotating telescoping boom attached by a

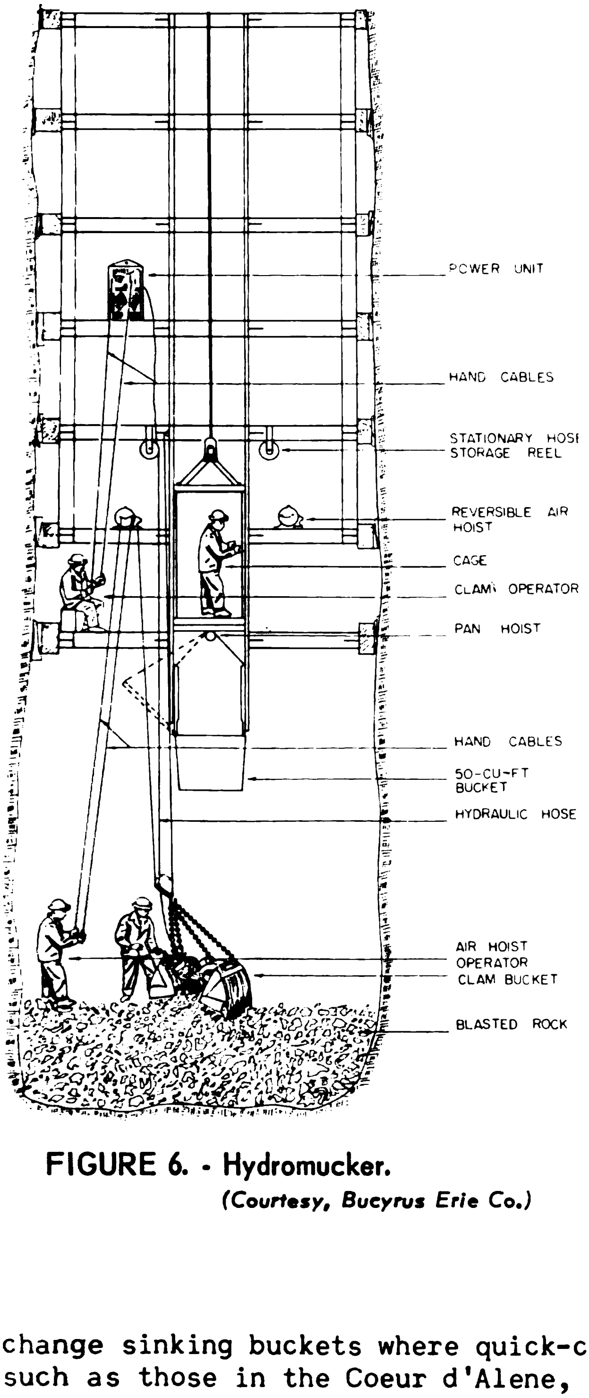

FIGURE 6. - Hydromucker.

(Courtesy, Bucyrus Erie Co.)

gimbal mounting to the underside of a regular mine cage that has been converted to a sinking cage. Four air cylinders under the cage control the swing or lateral movement of the boom, and another cylinder within the boom adjusts its length from 17 feet in the fully retracted position to 28 feet when fully extended. Two 6-inch air cylinders control the digging action of a clamshell bucket, which completes the resemblance to an arm and hand. The machine is controlled by two levers, which operate eight multiple-direction air valves.

Both shafts in which the Cryderman was employed had three compartments; in each case the mucker occupied the center compartment, pumps and utility lines were placed in the manway, and the sinking bucket or skip used the outside hoisting compartment. The Cryderman was converted for use in the inclined shaft by eliminating the rotating feature of the boom to keep the clamshell bucket in a fixed position parallel to the horizontal axis of the shaft. This was necessary to gain sufficient headroom to dump the bucket in restricted quarters. Another advantage of the nonrotating clamshell was not premeditated: Since the shaft was inclined, the bulk of broken rock lay against the footwall side in a position favorable for mucking by the fixed clamshell.

Only one man is actually necessary for the mucking cycle, though in other districts three men are used, one to operate the machine, and two others to change sinking buckets where quick-change buckets are used. In smaller shafts, such as those in the Coeur d'Alene, it is neither safe nor necessary for a man to remain in the bottom while mucking is in progress.

A fourth mucking machine was developed by Hecla Mining Company to overcome one of the major shortcomings of standard machines, namely, loss of efficiency in small shafts. The machine, though smaller, is similar in principle to the hydromucker in that it consists of a self-powered clamshell bucket raised and lowered by air hoist. The major difference lies in the design of the bucket proper. The jaws are designed about a central pivot point which

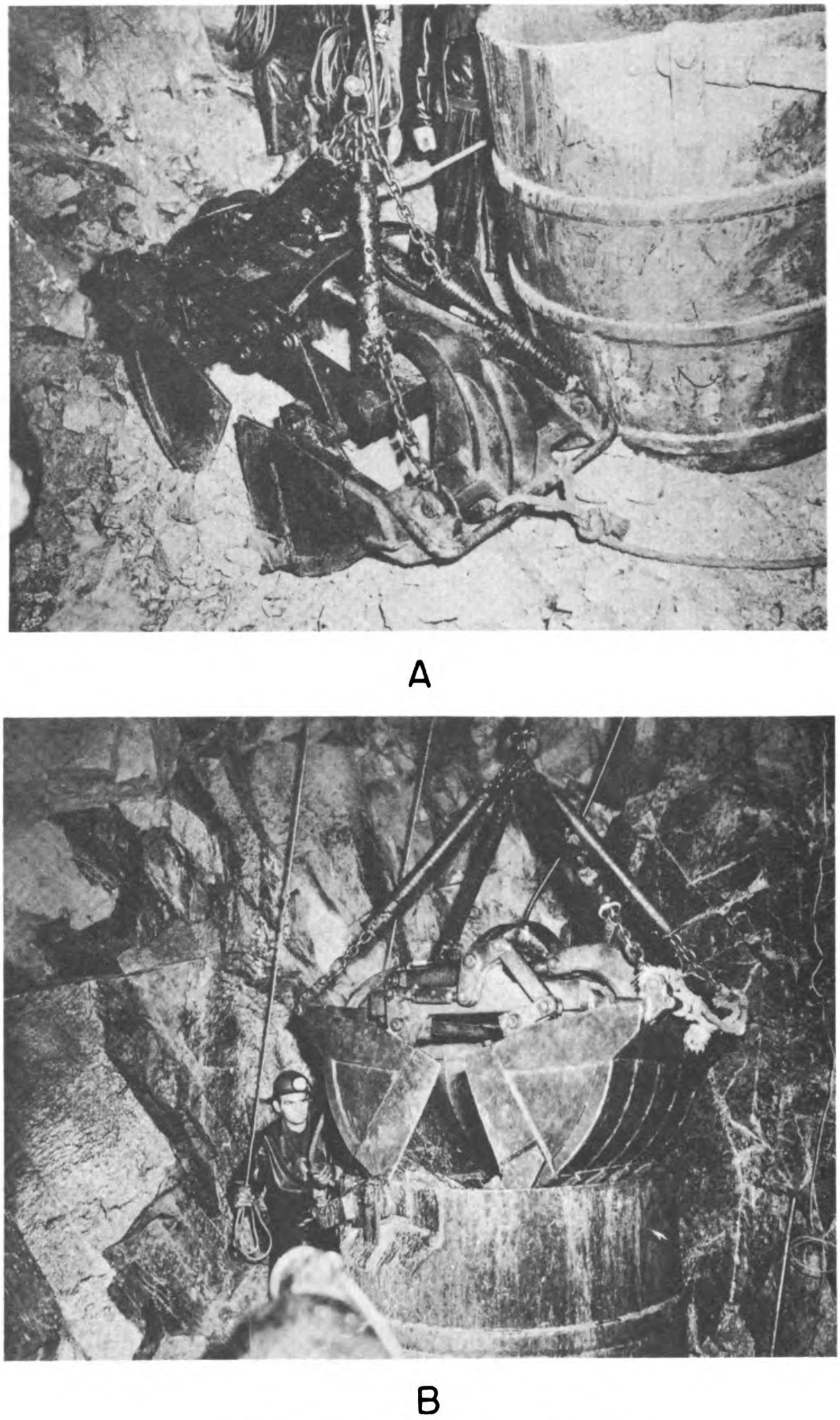

FIGURE 7. - Hydromucker in Operation.
A. Loading; B. Dumping.

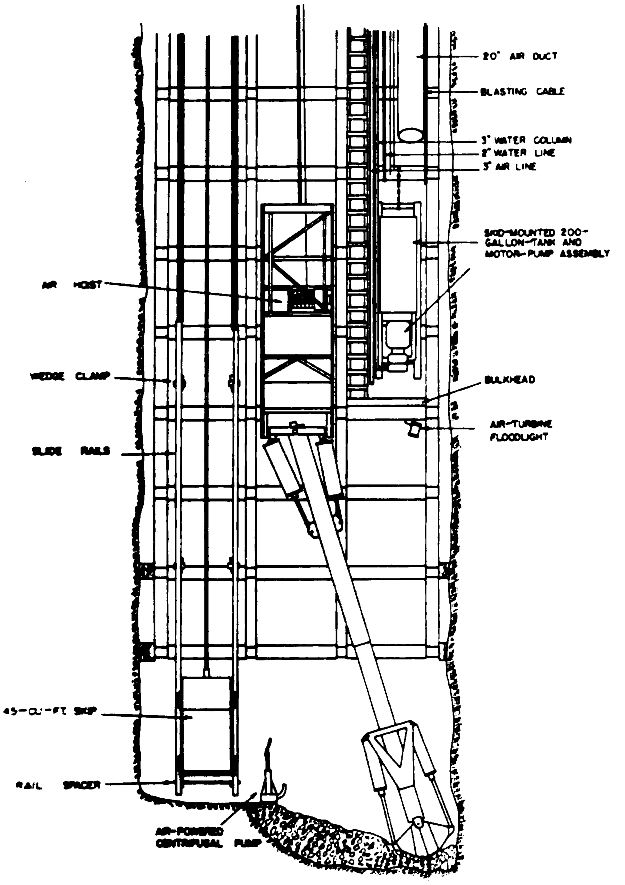

FIGURE 8. - Cryderman Mucker (18).

provides a tremendous mechanical advantage to the double-acting air cylinder that opens and closes the jaws. The positive digging action so obtained is very effective. Two men are required for its operation, one to position the bucket for digging and dumping, and another to operate the machine and air hoist. The clamshell bucket has a capacity of 9.8 cubic feet, and two passes usually are sufficient to fill the sinking bucket.

HOISTING

Stage hoisting is practiced in extending deep operating shafts for two reasons: Interference with the use of the main mine hoist for other activities is minimized, and shorter hoisting distances permit more rapid mucking of the shaft bottom. Transfer pockets (fig. 10) or intermediate dump pockets are installed at a station above the sinking project. In some cases a sinking hoist, installed specifically to service the sinking project, raises waste to the intermediate dump pocket to be transferred and moved the remaining distance by the regular mine hoist. This arrangement offers the advantage of minimum interference with other mining activities. Occasionally, when the regular mine hoist is used in sinking, intermediate pockets are used as surge bins to shorten the mucking-hoisting cycle.

In shallow or secondary shafts and winzes, where the hoisting cycle is less likely to interfere with other mining activities and the hoisting distance is usually much less, waste rock is normally hoisted in a single lift.

Sinking skips and buckets range in size from 10 cubic feet to 95 cubic feet, with the Kimberley-type overturning skip predominating, though some bottom dump skips are also used. Sinking buckets are usually dumped by overturning.

PUMPS

Waterflow ranged from less than 10 to more than 200 g.p.m., though in general it was not a serious problem. Air-powered sump pumps delivered water from the shaft bottom to moveable tanks placed in the manway 25 to 75 feet above the bottom. Centrifugal motor pumps then relayed the water in a single stage or in multiple stages, through the use of additional tanks and pumps, to the surface or to sumps where the water entered the regular mine pumping system.

Air-powered sump pumps of the type known as sponge pumps are the most common. Normally rated to deliver 150 g.p.m. at 100 feet of head, two pumps in tandem have been known to reach heights in excess of 200 feet with the aid of an air jet.

Electric sump pumps have generally been unsatisfactory because of moisture conditions and the shock hazard present because of the lack of suitable waterproofing. One particular type, however, a self-priming, low-head, high-volume pump designed to handle water containing 40 percent solids, was successfully used in one project which had excessive waterflow. The initial cost of the pump was high (about $1,000), but in performance it surpassed the air-powered sump pump which it replaced.

TIMBERING

A standard shaft set consists of 2 wall plates, 2 end plates, 6, 8, or 10 posts, and 1, 2, or 3 dividers depending upon the size of the shaft (figs. 11, 12, and 13).

Heavy members range from 8- by 8-inch to 12- by 12-inch, locally grown red fir timber purchased from custom-framing mills or framed at the mine. Surfaced clear fir is ordinarily used for shaft guides, and mill-run second- and third-grade fir and larch is used for lagging and lacing.

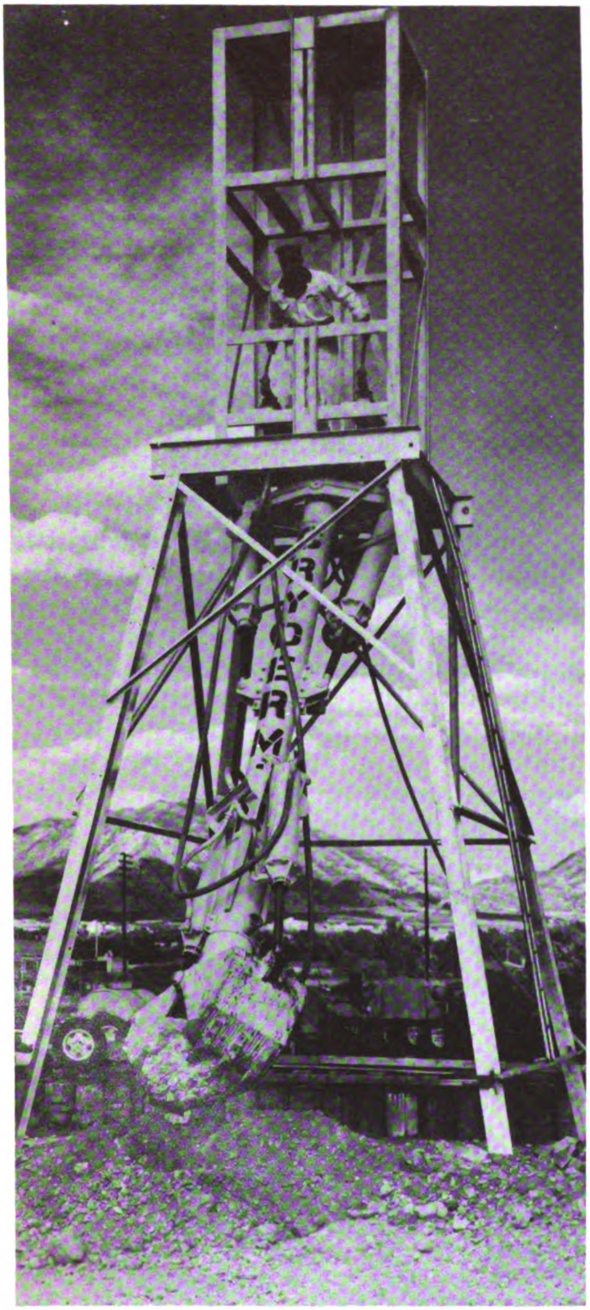

FIGURE 9. - Cryderman Mucker in Operation.
(Courtesy, Shaft and Development Machines, Inc.)

Shaft excavations, where ground conditions permit, are advanced two or three sets ahead of timber, and the sets are placed one or two at a time. Where ground conditions are poor, or mucking is by hand, timber is installed as near the face as possible. A steel blasting set or battleship protects the bottom timber from blasting damage and

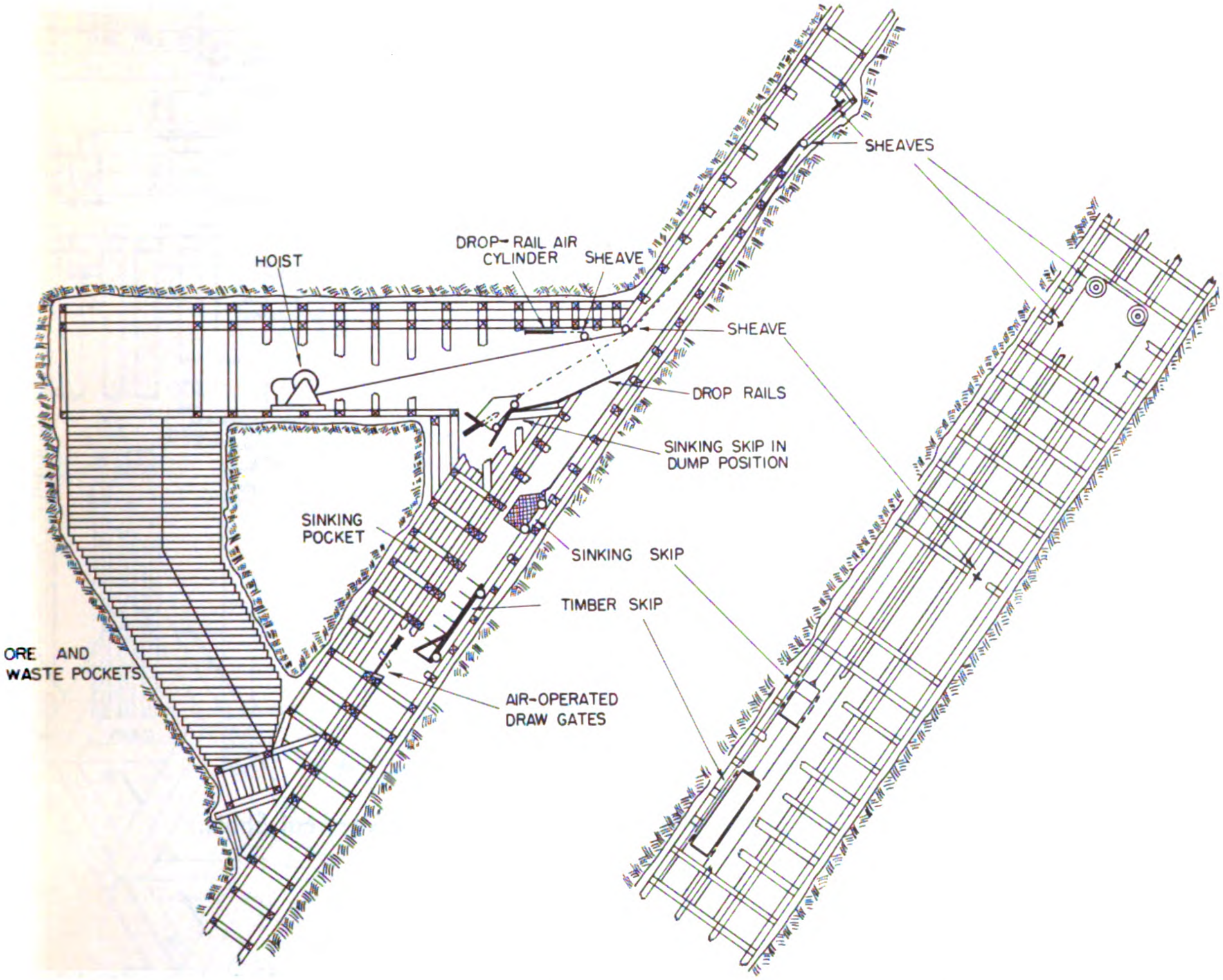

FIGURE 10. - Transfer Station and Sinking Pocket for Inclined Shaft (18).

is also used as staging when timber is installed. Shaft dividers are temporarily omitted from the bottom two or three sets to facilitate operation of mucking machines.

When loose ground or overbreak is encountered, jacket sets and keyboards are used in addition to the regular sets to maintain alinement and provide adequate support. Bearing stulls are seldom used; shaft sets are usually supported by threaded hanging rods. Bearing sets consisting of regular sets with extra-long wall or end plates to fit in hitches cut in the walls of the shaft are used at intervals of 100 to 400 feet. In some shafts, notably the Crescent, extra-heavy rock bolts (fig. 14) are used instead of wall hitches for timber anchors. In several shafts, ground movement provided sufficient anchorage without using bearing sets.

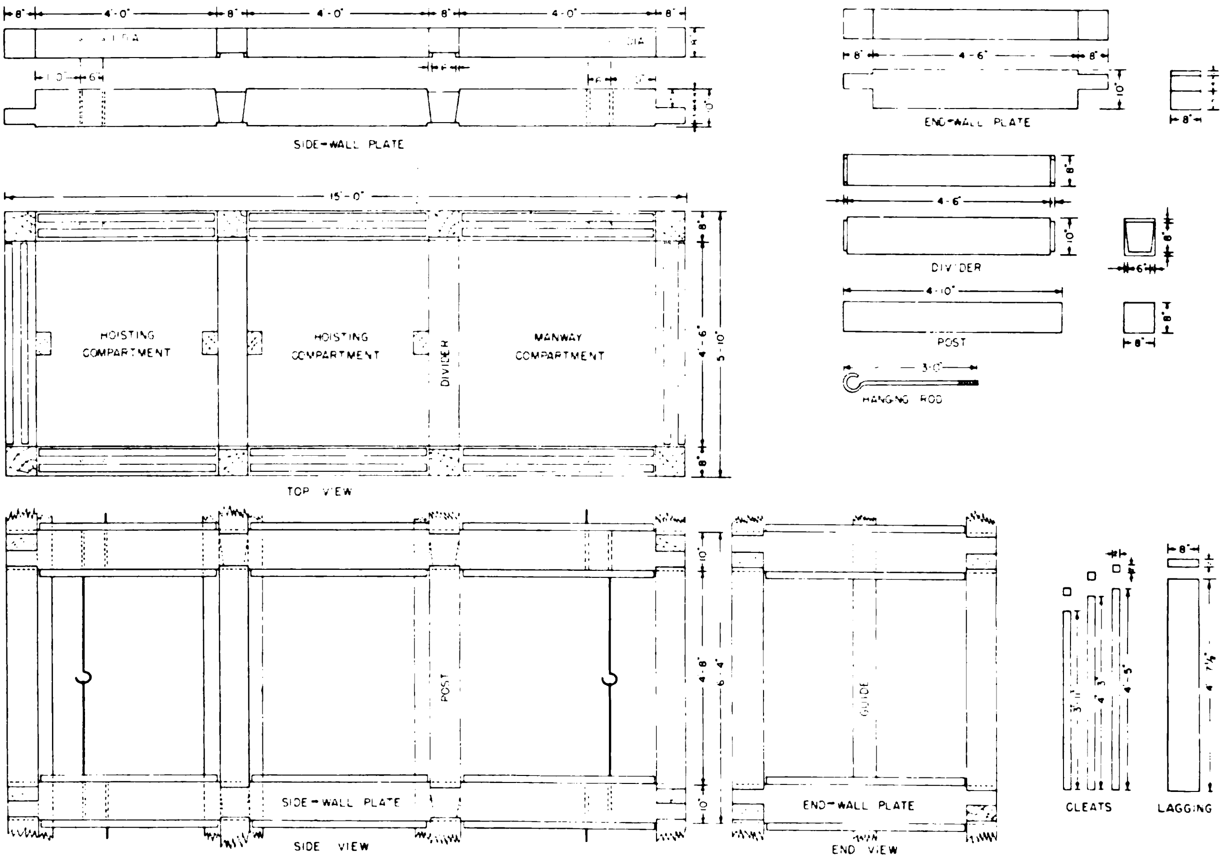

FIGURE 11. - Timber Detail of Three-Compartment Vertical Shaft.

VENTILATION

The usual method of ventilation while shaft sinking is through 18- to 24-inch-diameter 10- to 16-gage metal ventilation lines extending to within 30 to 50 feet of the bottom. A fan located near the collar of the shaft forces fresh air to the face at a pressure of 7 to 10 inches of water. If the fan is reversible, the system is changed shortly before blasting, and fouled air is exhausted through the ventilation line. Otherwise compressed air is released near the bottom to speed up the dispersion of foul air. Reentry to the bottom is usually possible 20 to 30 minutes after blasting.

Dilution of the fouled air after it leaves the shaft is a problem in some mines, particularly those in which contaminated air enters the main fresh-air circuit. In most cases the volume of fresh airflow is sufficient for dilution, or it may be possible to blast at such a time that the mine will be vacant until the air has cleared. Air scrubbers and water curtains can be installed to filter the air and absorb noxious gases. The latter system was used very effectively in the Page shaft.

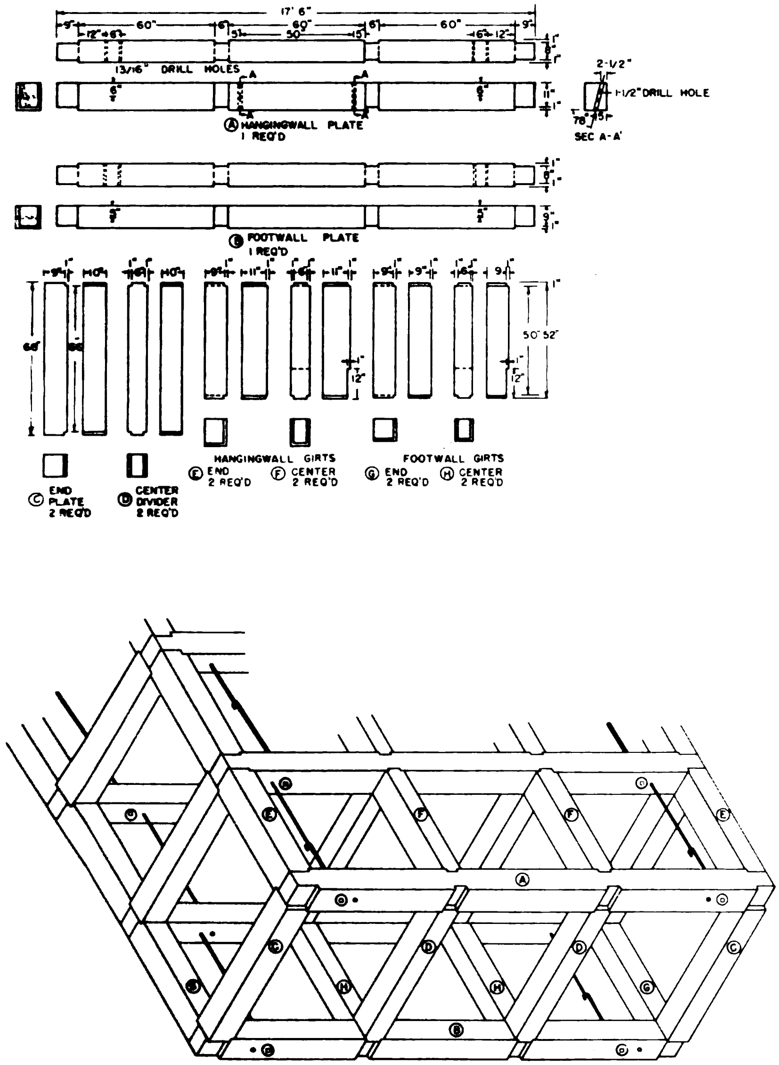

FIGURE 12. - Timber Detail of Three-Compartment Inclined Shaft (18).

LABOR

Shaft sinking is one of the more exacting jobs in a mine, and consequently requires miners of greater than ordinary skill and experience. The use of contract and bonus systems to attract and hold competent shaftmen is universal in the district.

Contracts are usually let to the bottom crew only and specify the quantity and quality of work to be performed, the equipment, supplies, and services to be furnished by the company, and the price to be paid per foot of advance. The usual contract includes breaking, mucking, timbering (including rock bolting where necessary), and utility installation. Work other than specified by contract may be done by shaftmen at their standard wage rate (day's pay) or by noncontract miners.

In recognition of the importance of noncontract crew members, a bonus is usually paid the hoistman and other regularly assigned crewmen. The bonus is computed as a percentage of the amount earned by shaftmen above what would have been earned on day's pay.

The following is a description of a representative contract:

The shaft is 17 feet by 7 feet 10 inches in rock section and is in hard, competent ground. Nineteen men comprise the sinking crew; 4 shaftmen, 1 skiptender, and 1 hoistman on each of three shifts plus a mechanic on day shift. The contract rate is $67.00 per foot advance and is shared equally among the shaftmen. The hoistmen, skiptenders, and mechanic are paid standard wage rates and in addition receive bonuses as follows: Skiptenders and mechanic receive bonuses equal to 40 percent and hoistmen bonuses equal to 20 percent of the amount shaftmen earned above day's pay.

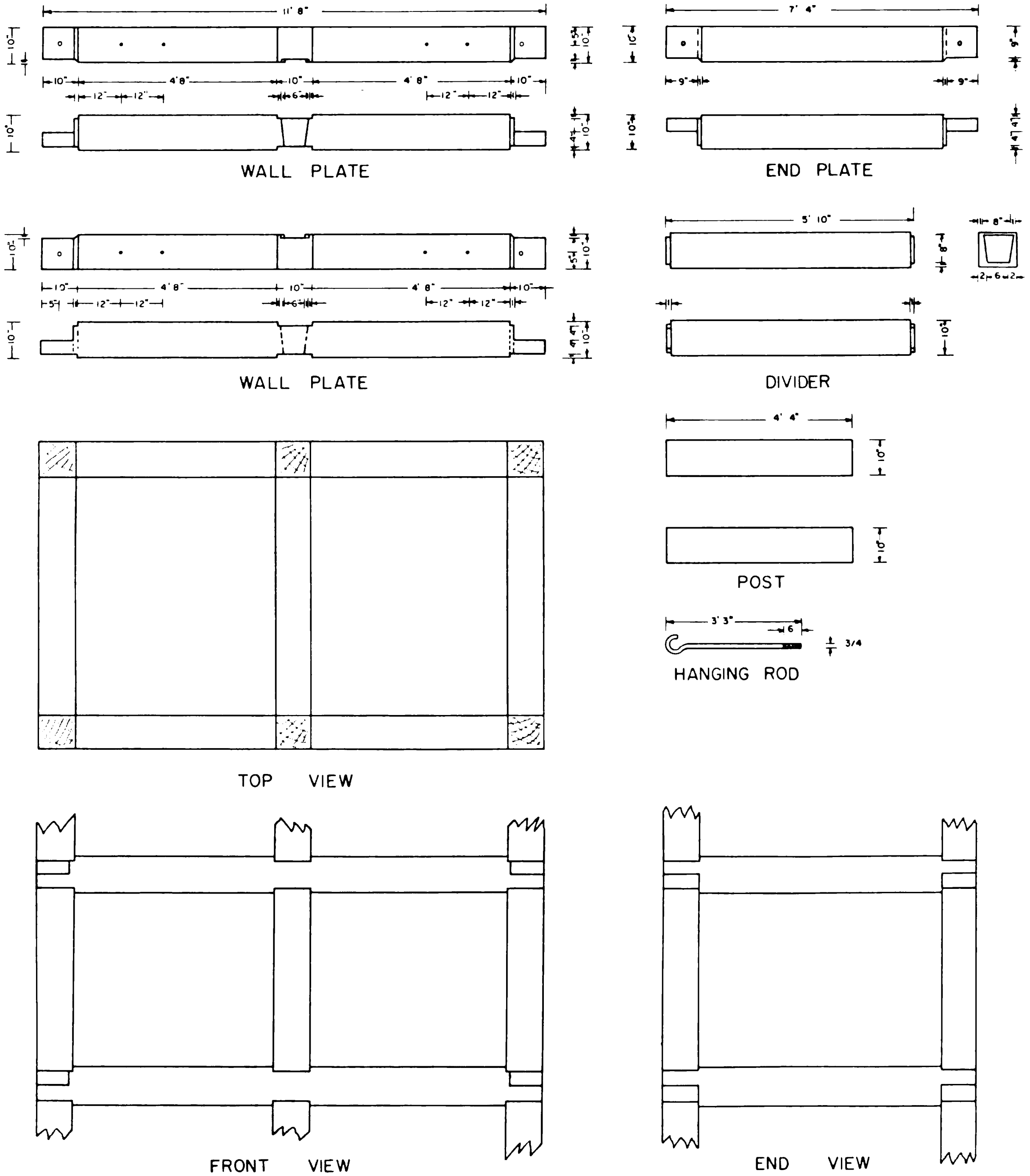

FIGURE 13. - Timber Detail of Two-Compartment Vertical Shaft.

All timbering, blocking, lagging, guides, ladders, etc., must be installed and maintained in a workmanlike fashion; all sets must be plumb with lines established by company engineers; compressed air, water, and ventilation lines are installed by the crew as needed; maintenance of timber, guides, utility lines, and similar functions necessary to the safe and efficient advancement of the shaft are done by the crew; timber, equipment, and supplies are furnished by the company delivered to the mine yard.

Contracts are usually informal or semiformal in nature and may be spelled out in greater or less detail than in the above example. Either party may cancel the contract, and work will proceed on day's pay until other arrangements are made. In no case does a workman receive less than standard wage rates.

A bidding system, whereby employees with greater seniority are given preference, has been instituted at several mines but has not been very satisfactory. Shaft labor turnover at one such operation amounted to 162 percent compared to 8 percent at two other mines not using the system.

Labor costs vary widely from shaft to shaft within the range shown by table 2.

TABLE 2. - Range of labor costs

		Bottom crew	Support labor	Nonwage costs	All labor
Labor cost per linear foot.	High.....	$104.93	$72.09	$24.52	$175.28
	Low......	48.81	20.66	4.07	97.08
	Average..	79.93	44.92	10.98	135.83
Labor cost per cubic foot.	High.....	.71	.65	.22	1.58
	Low......	.38	.13	.03	.64
	Average..	.51	.30	.07	.88
Labor cost per man-hour.	High.....	6.77	2.57	.52	9.50
	Low......	2.29	1.43	.11	3.95
	Average..	4.37	2.14	.27	6.78
Average percent of total cost...	....	38.0	22.9	5.6	66.5

Near-uniform wage rates are individually negotiated by several of the larger companies and by a coalition of smaller companies known as the Sixteen Operator group. The majority of workmen in the district are represented by Local 18 of the International Union of Mine, Mill, and Smelter Workers. Representative wage rates for the period June 30, 1956, to June 30, 1959, are shown in table 3.

TABLE 3. - Representative daily wage rates[1]

	1955	1956	1957	1958
Sinking shaftman........	$17.69	$18.95	$19.59	$20.23
Drift and raise miner...	17.23	18.03	18.63	19.23
Hoistman (single drum)..	16.31	17.11	17.67	18.23
Skiptender..............	16.31	17.11	17.67	18.23
Sanitation nipper.......	16.31	17.11	17.67	18.23
Powderman, nipper.......	15.85	16.65	17.19	17.73
Underground labor.......	15.39	16.19	16.71	17.23

[1] Effective July 1 of each year.

ATLAS MINE

Main Shaft

The Atlas shaft, 1 mile east of Mullan, was sunk in 1952 and 1953 as a joint venture of Hecla Mining Co., Newmont Mining Co., New Jersey Zinc Co., and Atlas Mining Co., in order to explore for downward extensions of favorable ore-bearing structures exposed near the surface in the Atlas mine workings.

Prior to actual sinking operations, the Atlas tunnel was enlarged and regraded, and 9,200 feet of new 30-pound rail was installed from the portal to the shaft station to permit the use of 40-cubic-foot rocker dump cars. In addition, a hoist room and rope raise was excavated, the shaft raise was extended, the old shaft was dewatered and repaired, and the surface plant was renovated.

The three-compartment shaft, measuring 16 by 7.2 feet outside timber, was extended from the 800 level to the 2400 level, an actual distance of 1,661 feet.

The sinking method was not unusual. Originally, a full-bottom round was successfully used, but lack of a sump and the difficulty of collaring drill holes in water and loose muck led to its abandonment in favor of a bench round. Either 24, 27, or 30 holes, depending upon the nature of the ground, were drilled for each round and broke an average of 5.6 feet per bench for an average full-bottom advance of 2.8 feet. Two 3-inch drifters, mounted on a 3-inch air bar and using 1-inch hexagonal alloy steel in 30-inch changes, were used in the sinking operations. Holes were collared with a 2-3/8-inch tungsten carbide-insert bit to a depth of 12 inches and cased with 2-inch pipe. Four-wing detachable tungsten carbide bits were used early in the sinking project but were later replaced with integral rods and tungsten carbide chisel bits with an improvement in performance. Drill penetration rates varied from 8 to 18 inches per minute, and bit and rod costs were slightly over 8 cents per foot of hole drilled.

All blasting was done electrically from the top station with regular-delay caps. Millisecond delays were tried but did not materially improve fragmenta-

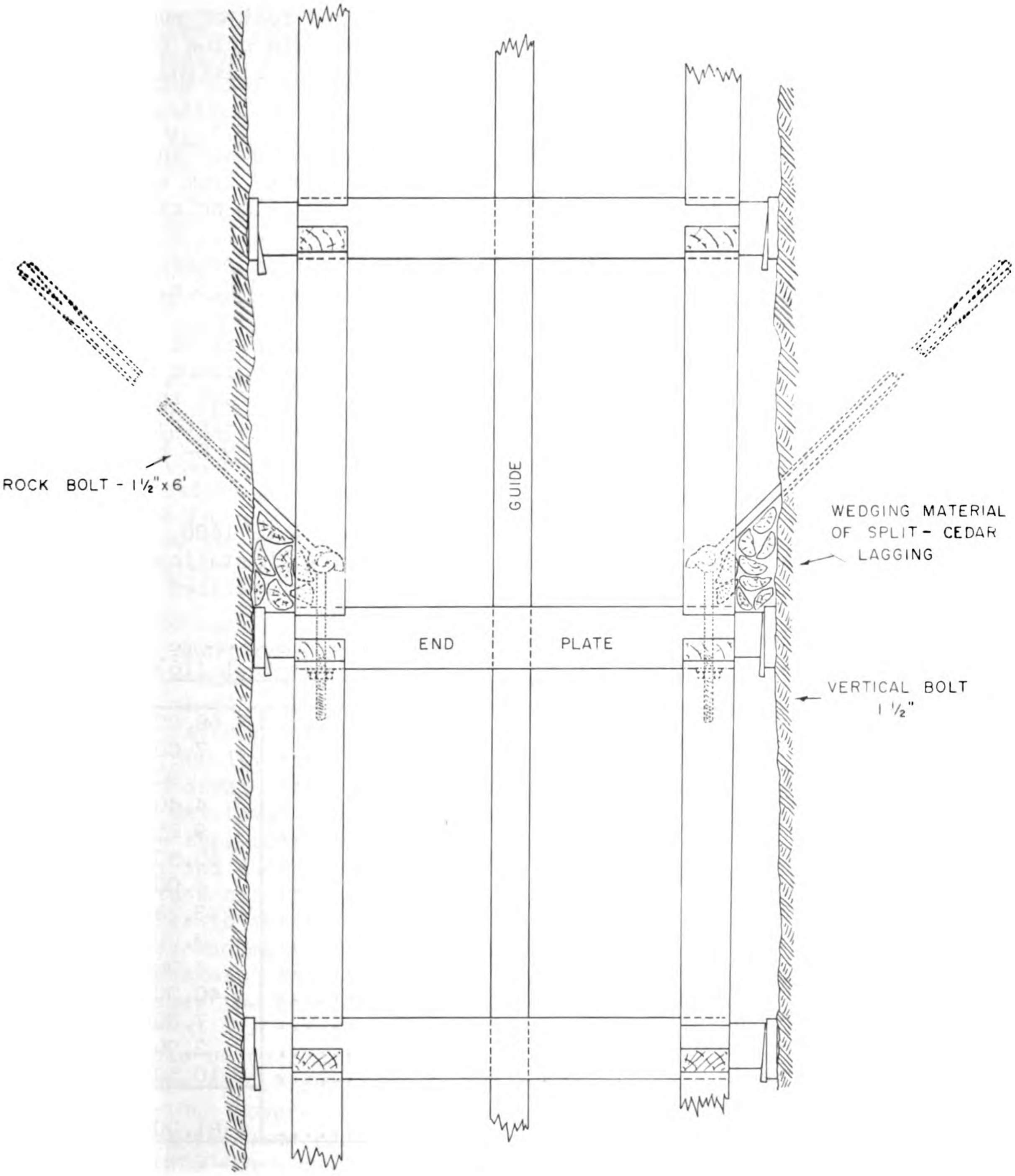

FIGURE 14. - Rock-Bolt Bearing Set, Crescent Shaft (17).

tion. Drill holes were loaded to the collar with 45-percent semigelatin dynamite and primed one stick above the bottom with one 1-1/8- by 8-inch stick of 60-percent gelatin. Occasionally, where a stronger blast was desired,

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60-percent dynamite was used as a booster charge. Powder consumption averaged 37 pounds per foot of advance or 0.23 pounds per cubic foot of rock broken. An all-steel false set, or battleship, suspended by chain below the lowest timber set, protected the shaft timber from fly rock during blasting and was later used as staging during installation of timber.

Mucking was with a Riddell 10-cubic-foot clamshell mucker into a 24-cubic-foot, self-dumping skip. The mucking machine was operated from a carriage supported on rails two or three sets above the bottom. All hoisting was in counterbalance and, through the use of an automatic skip dump, a dump man was not required. The hoist had tandem overwind drums and was powered with two 200-hp., 700-r.p.m. electric motors. Rope speed was 1,500 f.p.m.

Ground conditions were fairly good during the early part of the project, and timber was installed two sets at a time. Later, when ground control became a problem, timber was carried within 7 feet of the bottom, and rock bolts were installed in rings at 5-foot intervals. Split-wedge-type 1-inch-diameter rock bolts tightened with an impact wrench were used with 3/8- by 8- by 8-inch plates.

Stations were cut at 400-foot intervals, at the 1200, 1600, 2000, and 2400 levels. Tank sumps and pumps were installed at each station in series to relay water from the bottom. Shaft-sinking costs are summarized in the following table:

TABLE 4. - Direct shaft-sinking cost, per foot (16)

Direct labor	$ 68.00
Bits and rods	7.00
Compressed air	.90
Drill repair	4.40
Explosives	9.25
Hoisting	15.80
Haulage	4.00
Pumping	3.25
Shaft mucker maintenance and royalty	3.00
Miscellaneous	4.00
Timber, pipe, etc	40.00
Dump and surface	7.00
Power	3.90
Overhead	10.50
Total	$181.00

CRESCENT MINE

Main Shaft

The Crescent mine, now owned by Bunker Hill Co., is on the west side of Big Creek, about 7 miles east of Kellogg. Records of its production prior to 1917 are not available, but from that time until 1942, when mining operations ceased because of the wartime manpower shortage and near exhaustion of the known ore bodies, 4,383,000 pounds of lead, 2,746,000 pounds of copper, and 6,078,000 ounces of silver were produced. The mine was developed through five adits, the lowest being the Hooper tunnel, from which a three-compartment underground vertical shaft extended 1,275 feet to bottom at an elevation of 1,434 feet. Virtually all exploratory work was confined to the immediate vicinity of the Alhambra fault and was directed toward development of ore shoots in and near that structure. Since experience in the district, and particularly at the neighboring Bunker Hill mine 2 miles west and the Sunshine mine 1 mile east, indicated that mineralization extends to sea level and lower, the decision was made to deepen the Crescent shaft 2,000 feet to about 400 feet below sea level and explore the block of ground lying between the Alhambra and Syndicate faults.

The project, started in March 1953 and completed in May 1954, involved rehabilitating portions of the existing surface and underground installations, dewatering and repairing the existing shaft, extending the shaft from 1,275.5 to 3,276 feet, and cutting four pump stations and one intermediate dump pocket (17). Actual sinking operations required 284 days: 238.6 days for shaft sinking, 41.4 days for station cutting, and 4 days lost by breakdown. The project was financed by the Bunker Hill Co. with the aid of a Defense Minerals Exploration Administration (DMEA) contract (No. Idm-E493).

The Hooper tunnel, unused since about 1943, was rehabilitated from the portal to the shaft collar, a distance of 4,000 feet, and heavier, 85-pound rail was laid. About 100 feet of retimbering was required in the sheave raise above the old shaft collar. Dewatering the shaft from the collar to the 800-foot level was accomplished in one lift with a 100-hp., 700-g.p.m. deep-well pump. On the 800 level, a temporary sump and 500-g.p.m. relay pump were installed, and dewatering to the 1200 level continued in two lifts. Shaft timber in the dewatered section was in good condition, and only ladders and platforms were replaced. On the surface the old office and change house were reconditioned, and a 400-ton surge bin was constructed to hold waste for transhipment by truck one-fourth of a mile to the waste dump. The sinking procedure was similar to the Atlas project in essential details. A 30-hole bench round was used, and mucking was by a Riddell clamshell mucker into a 21-cubic-foot sinking bucket. One major variation was the use of intermediate dump pockets to reduce the time consumed in hoisting during the mucking cycle.

The 30-hole bench round consisted of five rows of six 8-foot holes and broke an average of 6.2 feet for an overall shaft advance of 3.1 feet per round. Two 3-inch power-feed drifters mounted on a 3-inch pneumatic bar drilled a complete round from one setup. Drill steel was 1-1/8-inch round, hollow steel in 30-inch changes. Holes were collared to solid ground with a 2-1/2-inch detachable bit and cased with a 2-inch pipe. The remainder of the hole was drilled with carbide-insert detachable bits, 1-5/8 inches in diameter when new and sized after sharpening to obtain gage changes. Steel and bit costs together, including handling and sharpening, averaged $6.70 per foot.

Drill holes were loaded to the collar with 45-percent gelatin dynamite and fired electrically. Millisecond-delay detonators were used in the first row and standard delays in the rest (fig. 3). A steel blasting set made of 3/4-inch steel plate was held against the bottom of the lowest set by chains and wedges. Blasting costs, including explosives, detonators, wire, etc., averaged $9.59 per foot. Powder consumption averaged 0.24 pounds per cubic foot of rock broken.

A Riddell mucker, with a 10-cubic-foot, heavy-duty clamshell bucket, was operated from the second set of timber above the bottom. During the mucking cycle one shaftman operated the mucker carriage, another controlled the sinking bucket by bell signals, and two others on the shaft bottom barred down the walls and maneuvered the bucket into position for filling. Usually three passes were sufficient to fill the sinking bucket and required 1 to 1-1/2 minutes. The entire mucking cycle required 2 hours: 1 hour to load, hoist, and dump 30 buckets, and 1 hour to clean up the bottom in preparation for the next round.

The rope speed of the 250-hp., double-drum hoist was limited to about 800 f.p.m., and the size of the bucket was restricted by the opening. Consequently, hoisting in one stage with a sinking bucket to the haulage level would be excessively time consuming. An intermediate dump and loading pocket was established on the 1200 level, and later moved to the 2000 level, to transfer broken rock from bucket hoisting to skip hoisting. In this way muck could be hoisted from the intermediate pocket to the collar while other work was being done in the bottom. Men working on the bottom were protected from falling rock by steel deflection plates over the hoisting compartments and temporary lagging over the manway. Hoisting to the intermediate dump was in counter balance; while one bucket was being dumped (20 seconds) the other was being loaded.

Timber and other material used in sinking the shaft were received from the supply warehouses in packages. That is, all the preframed timber necessary for one shaft set would comprise one package and could be lowered from the collar in one trip. Timber was installed to within about 12 feet of the bottom. Dividers were temporarily omitted from the bottom three sets to avoid interfering with the operation of the mucking machine. Bearing sets, supported by eight 6-foot rock bolts, were installed at 400-foot intervals (fig. 14). Overall dimensions of the shaft were 5 feet 10 inches by 15 feet, outside timber, and sets were placed 5 feet 6 inches center to center. Installation required 2 hours and 43 minutes per set, plus 35 minutes every third set to install permanent guides.

Ventilation was accomplished by two 25-hp. blower fans; one in the sheave raise 60 feet above the shaft collar delivered 6,000 c.f.m. of fresh air to the shaft bottom through a 20-inch ventilation pipe. The second blower, placed at the collar, exhausted about 5.3000 c.f.m. from the shaft. During the blasting cycle, smoke was cleared in about 30 minutes by reversing the airflow and exhausting through the 20-inch pipe.

About 10 g.p.m. of water was pumped from the bottom by an air-powered sump pump, or by two pumps in tandem when the lift approached 200 feet. Permanent 25-hp. pumping stations were installed at 400-foot intervals below the

1250 level, and an auxiliary 25-hp. pump was used to supplement the bottom pumps for lifts greater than 200 feet.

Sinking operations were carried on three shifts per day, 6 days per week, by sinking crews consisting of four shaftmen, one skip tender, and one hoistman on each shift, plus a levelman on the day shift to bring supplies, tram waste, and maintain equipment.

Sinking costs are summarized in the following table:

TABLE 5. - Shaft-sinking costs (18)

	Cost per foot
Labor, direct	$112.79
Labor, indirect	34.99
Supplies	64.62
Power	4.28
Other	7.32
Total[1]	$224.00

[1] Includes $18.80 per foot site preparation charges.

HERCULES MINE

The Hercules mine was discovered in 1898, and incomplete records during its first period of activity from 1902 to 1925 show production of more than 2.5 million tons of ore containing 49 million pounds of lead and 20 million ounces of silver. The original ore shoot bottomed in pyrite-pyrrohotite, and, though the vein was known to continue, the mine appeared to be worked out and was abandoned in 1925. In 1947, Day Mines, Inc., gained control of the property, and a portion of the mine was dewatered with the hope of finding additional ore shoots in the persistent Hercules vein. Exploration on the lower levels in the western section of the mine disclosed sporadic occurrences of ore with evidence of mineralization strengthening with depth. In 1952, Day Mines undertook an extension of the exploration program and with the participation of the DMEA proceeded to dewater and extend the main shaft 313 feet to the 1600 level. A 1,000-foot crosscut was driven westerly on the 1600 level to intersect the Hercules vein. Drifting to the right of the intersection successfully proved the extension to the 1600 level of an ore shoot previously known on the 1000 level. Drifting to the left of the intersection was inconclusive, and in 1957 a 350-foot winze was sunk to examine the vein at the 1950 horizon.

Main Shaft

The main or zero level of the Hercules mine is the No. 5 adit, and its portal is within the limits of Burke, Idaho. The main shaft is 9,000 feet west of the portal and extends to the 1600 level. Preparations for extending the main shaft from the 1300 level to its present depth involved dewatering about 70 feet of shaft, constructing bulkheads to seal the shaft area from additional drainage, rehabilitating three of the original four compartments, and constructing an intermediate waste pocket on the 1200 level. The shaft was continued 8-1/2 by 19 feet in rock section by hand mucking.

A 30-hole bench round drilled with two 65-pound, hand-held jack hammers was used in the shaft. The holes were collared with 2-1/2-inch steel bits to a depth of 15 inches and cased with 2-inch pipe. The remaining depth was drilled with 1-1/8-inch round steel and detachable four-wing carbide-insert bits. Holes were loaded with 40-percent special gelatin and detonated with regular electric delays from a blasting station on the 1200 level. Powder consumption was 37.2 pounds per foot advance or 0.22 pounds per cubic foot of rock broken. Mucking was by hand into an 8-cubic-foot pan, which was dumped by an auxiliary hoist into two 16-cubic-foot sinking buckets hoisted in balance by the main hoist to waste pockets on the 1200 level. Automatic steel doors protected the shaft bottom from spill rock. About once a week, contents of the 1200 pocket were hoisted by skip to the main level and trammed to the surface. During sinking operations, other activities in the mine were at a virtual standstill, and use of the main hoist for sinking caused little inconvenience. The main hoist was a 750-hp., 600-v., d.c., double-drum unit with Ward-Leonard control capable of hoisting two 5-ton skips in balance at a speed of 2,000 f.p.m.

The shaft was timbered with standard Coeur d'Alene sets carried close to the bottom for convenience in installation. Bottom sets were protected by wooden blasting sets.

Bottom ventilation was provided by a 15-hp., reversible-flow fan operating through a 20-inch ventilation pipe in the manway. Normally, the flow was downcast to deliver fresh air to the bottom. The flow was reversed during blasting to evacuate smoke and dust. Evacuation required about 20 minutes.

An air-powered high-head sump pump relayed water to a 100-gallon tank in the manway where it was pumped to a sump on the 1000 level by a 20-hp., two-stage, centrifugal motor pump. The regular mine pumping system relayed the water at 575 g.p.m. to the gravity-flow drainage level (No. 5 adit) with a 200-hp. multistage motor pump.

No. 444 Winze

Sinking of the two-compartment No. 444 winze differed only in detail from the method used to extend the main shaft. Inasmuch as the winze was collared on the sill of the 1600 level, it was necessary to construct a complete underground hoisting station. This included excavation of a rope raise, a sheave raise, and a dump pocket above the level, and enlargement of the 1600 station to include a hoist room and car-loading facilities.

The winze was sunk by two two-man bottom crews using hand-held sinker drills and mucking by hand. An 18-hole bench round was used because of the smaller (13.0- by 8.5-foot) rock section of the winze, but powder consumption

(0.29 pound per cubic foot of rock broken) was somewhat greater than in the main shaft. Mucking was by hand directly into a 13-cubic-foot sinking bucket, in contrast to the main shaft where pans and two sinking buckets were used. Winze waste was hoisted to the 1600 level and trammed to the main shaft.

Timbering methods (standard Coeur d'Alene sets) and material (10- by 10-inch red fir and panel lacing) were identical with the main shaft, although only 200 board feet per foot were needed compared to 310 board feet. Ventilation and pumping were identical to the point of using the same pumps and fan.

LUCKY FRIDAY MINE

No. 2 Shaft

The No. 2 shaft of the Lucky Friday mine was extended from the 2365 level to the 3143 level in 1957 to explore for downward extensions of the Lucky Friday ore zone. The shaft is unusual in that it started as an underground winze, was raised to intersect a new adit in which hoisting equipment was installed, and then was sunk from the bottom of the winze to its present depth.

The mine is adjacent to U. S. Highway No. 10 about three-fourths of a mile east of Mullan, Idaho, in an area that was historically devoid of major mineralization. The original outcrop was located in 1899; in 1926 considerable exploration on what is now the main portal level disclosed only a narrow vein a few inches wide. The property was idle until 1939 when a 100-foot, 1-1/2-compartment shaft was sunk from the main level 2,000 feet from the portal. The results were unpromising, but the shaft was continued in the unproductive Wallace formation to the 300 level where the more promising St. Regis formation was entered. The narrow vein widened to minable widths, and the shaft extended in stages to the 600, 800, 1000, and finally the 2000 level. Mineralization on the lowest level warranted further exploration at depth, and a winze was sunk 375 feet south of the shaft to reach the 2300 level. Inasmuch as the original shaft had limited hoisting capacity, a second shaft was raised from the winze to the main haulage level, and a hoist room was cut and hoisting equipment installed. No. 2 shaft was then extended from the bottom of the winze to its present depth 3,143 feet below the adit level.

Sinking the No. 2 shaft involved no special problems. Production work in other parts of the mine above the 2300 level continued without interruption through the No. 1 shaft and through two compartments of the No. 2 shaft.

Bench rounds of 25 to 30 holes per round were drilled with hand-held 55-pound sinker drills using 7/8-inch-diameter lugged steel in 2-foot changes. Holes were collared with 2-1/4-inch steel bits to a depth of 18 inches, cased with 2-inch pipe, and continued with integral steel and carbide chisel bits. Drill holes were primed with 60-percent dynamite and loaded to the collar with 45-percent semigelatin dynamite. Charges were detonated with regular 1 through 10 electric delays fired by a 220-volt blasting circuit from the 2300 level. The average round broke 5.0 feet, an advance of 2.5 feet for the full 9- by 20-foot rock section. An average of 0.16 pound of powder was used per cubic foot of rock broken. Drilling required about 2 hours and loading about 40 minutes.

Much of the gas and smoke released by blasting was absorbed by a large flow of water in the shaft; the remainder was blown out of the bottom with compressed air and diluted on the 2300 level by the 35,000-c.f.m. main-mine airflow. From 20 to 30 minutes were required to clear the bottom enough to reenter.

The shaft was mucked with a Cryderman mucker blocked with wedges in the middle compartment of the three-compartment shaft 20 feet above the floor. All the controls, including those for the air hoist used in positioning the mucker and raising it during a blast, were contained in the carriage within easy reach of the operator. A 30-cubic-foot, Kimberley-type sinking bucket suspended in the sinking compartment was controlled by the mucker operator with signals. Since other operations in the mine shared the use of the shaft above the 2300 level, a waste dump and skip pocket were installed on this level. A 100-hp. auxiliary hoist raised the sinking bucket to the 2300 level, where muck was transferred to the main-hoist skip pocket and later hoisted to the adit level by two 2-ton skip cages operating in balance. Because of the size of the shaft and the equipment used, no one was allowed in the bottom during mucking; cleanup and barring down the walls was done while hoisting. The usual time for mucking and hoisting 30 buckets was about 2-1/2 hours. About 3 minutes was required to fill a bucket, though the time might run as high as 7 minutes when large unbroken slabs of rock were encountered.

Standard shaft sets were carried to within 15 to 20 feet of the bottom. Dividers were left out of the bottom two or three sets to facilitate use of the Cryderman mucker. About 3 hours was required to install a set of timber; one member of the three-man bottom crew usually installed ladders and lagging during the drilling cycle.

Waterflow in the shaft ranged from 150 to 175 g.p.m. to more than 200 g.p.m. for periods of several days. Sump pumps were used at the start, but because of the volume of water and excessive maintenance costs they were replaced by a high-volume, low-head, submersible deep-well pump designed to handle water containing up to 40 percent solids. The pump, with a self-contained 6-hp., 220/440-v., 3,400-r.p.m. motor in a waterproof housing, was lowered to the bottom immediately after blasting. Water was pumped through 3-inch hose to a 75-gallon sump and a 20-hp., air-powered relay pump 40 to 50 feet above the bottom. Another pump in series was required to relay water to the 2300 level to enter the regular drainage system.

The sinking crew consisted of three contract shaft miners and one hoistman (auxiliary hoist) on each of the three daily shifts. In addition, a nipper on day shift supplied the shaft with timber and other supplies. The initial contract price (for nine bottom men) was $60.00 per foot of advance; later it was $62.50.

PAGE MINE

Main Shaft

The Page mine, 7 miles southwest of Kellogg, is owned and operated by the American Smelting and Refining Co. The deposit was discovered before 1906, but because of the difficulty of extracting a marketable product from the finely disseminated ore by gravity methods, the property was not productive until after the advent of flotation. The main shaft was sunk to the 600 level in 1911, to the 1200 level in 1930, to the 3070 level by 1950, and to the 3450 level in 1956-57. The three-compartment shaft, inclined at 51° near the surface and 55° below the 1200 level, was sunk to the present level to develop the Tony vein, which has been the source of nearly all production, and to explore several other veins from which little or no production was realized on the upper levels. Since the mine was in operation and this was to be an extension of the main shaft, no site preparation was necessary other than cutting shaft waste pockets, installing a sinking hoist on the 3070 level, and dewatering the existing sump. Sinking started 110 feet below the 3070 level, the lowest operating level in the mine. A Cryderman mucker was modified for use in the inclined shaft, the first such application in the United States.

The three-compartment shaft, 8-1/2 by 20 feet in rock section, was oriented with the long axis parallel to the bedding.

A bench round of 20 holes drilled to about 7 feet in depth (fig. 4) broke 6.6 feet per round for an average full-bottom advance of 3.3 feet. About 75 percent of the holes were drilled with air-leg-mounted 55-pound sinker drills; the remainder were drilled with hand-held machines. The sloping bottom, kept normal to the plane of inclination, made it difficult to drill with conventional hand-held machines but was well suited to drilling with an air-leg. Setup time was materially reduced by a specially designed drill platform on which the machines were lowered to the bottom with hoses already connected to an air and water manifold built into the platform. Two hoses with snap-on couplings supplied air and water to the manifold. When drilling was completed, the machines were placed on the platform, the supply hoses were disconnected, and the platform was hoisted to the station. All holes were collared to a depth of 16 to 20 inches with 2-1/2-inch steel bits and cased with 2-inch pipe. The remaining depth was drilled with integral chisel bit steel. Average time for drilling and blasting one bench round was 3 hours and 40 minutes. Standard-delay caps and 40-percent gelatin dynamite were used in blasting. Powder consumption was 0.11 pound per cubic foot.

An air scrubber and water curtain protected the rest of the mine from smoke and fumes during blasting in the shaft. A 15-hp. reversible fan installed in the 3070 shaft station ventilated the bottom through a 20-inch air duct. After a blast the flow was reversed and exhausted into a scrubber containing water sprays and filters. In addition, a water curtain in the ventilation drift prevented contamination of the mine airflow. All smoke and gas was cleared from the bottom in about 25 minutes.

Mucking was with a Cryderman machine, which was adapted for use in the inclined shaft, where headroom is limited, by replacing the rotating boom with a nonrotating boom. Nearly all the broken rock lay against the footwall and was easily mucked with the nonrotating clamshell parallel to the footwall. This position also provided the greatest clearance for dumping into the sinking skip.

To prepare for mucking, broken rock under the skip compartment was cleared away to install skid rails for the skip. The 45-cubic-foot skip was then lowered to the bottom, and mucking was started. The actual mucking operation required only two men, the mucker operator and hoistman. No one was permitted in the bottom while mucking was in progress. The shaft crew installed air and water lines during the mucking cycle, and the small amount of pump moving and scaling that was necessary was done while the skip was being dumped.

An intermediate dump pocket and a 150-hp. hoist were installed on the 3070 level to service the shaft-sinking project. Drop rails were used to switch the 45-cubic-foot, self-dumping sinking skip from the shaft to the waste pocket (fig. 10).

A special timber skip was used to lower a complete set of timber from the surface to the 3070 level. The timber was transferred to the sinking skip in the order in which it would be installed and lowered to the bottom. The set was then loosely assembled in place, tightened with the mucker hoist, and blocked in place. Timber was carried to within 5 feet of the face. Dividers were omitted from the bottom sets to provide clearance for the mucker, the hanging wall plate being supported by two 6-foot expansion-shell rock bolts. Additional ground support was obtained from rings of nine rock bolts installed between each set.

A maximum of 60 g.p.m. of water was pumped from the shaft bottom. An air-driven sump pump in the bottom of the shaft pumped to a 200-gallon, skid-mounted tank in the manway compartment where it was relayed by a 30-hp. float-controlled pump to a settling tank on the 3070 level.

SIDNEY MINE

Main Shaft

The Sidney mine was opened in 1896 but was not extensively explored or developed until 1926 to 1934, when the Sidney Leasing Co. produced 187,000 tons of ore. The Sidney Mining Co. resumed operations in 1942, and from that time to the present a vigorous program of exploration and development has been underway. In 1948 a new main-level adit was driven, and subsequent deep exploration was conducted from a shaft located 2,300 feet inward from the portal. The shaft was extended to the 1500 level in 1953 and to the 1700 level early in 1954. Later in the year and in 1955, the shaft was continued to the 2300 level with participation by the DMEA.

The mine is located in the Pine Creek area of the Yreka district, about 5 miles southwest of Kellogg. The ore deposits of the Pine Creek area are confined to the Prichard formation and are characteristically replacement bodies along zones of shearing, fracturing, and faulting. The deep exploration was undertaken to explore for downward extensions of the Sidney ore structure and to investigate the McDougall fault and Yreka shear zone for commercial mineralization. In this area the country rock is hard, strong, thin-bedded argillite of the Prichard formation, dipping 55° to 70° N.

No particular site preparation was necessary. Shaft sinking continued from the existing sump below the 1700 level after an intermediate waste pocket was cut on the 1700 level. The main hoist was used to raise broken rock to the 1700 level during the mucking cycle and later from the 1700 to the surface while other work continued in the bottom.

A 36-hole bench round was drilled with two 3-inch drifters mounted on a 3-inch air bar. Four rows of six holes each were drilled in front of the bar and two rows behind the bar. Holes were collared with 2-1/2-inch carbide-tipped bits and cased with short lengths of 2-inch pipe. The remainder of the hole was drilled with carbide-tipped chisel bits and 1-inch hexagonal steel. Holes were drilled 7 to 7-1/2 feet and broke to 5.6 feet. Rod life was over 300 feet, and steel cost was less than $0.07 per foot of hole.

All holes were loaded with 60-percent special gelatin dynamite. Improved fragmentation was achieved by detonating the first several rows with millisecond-delay caps; the remaining holes were detonated by regular-delay electric caps. Slightly more than 3 hours was required for drilling and blasting—35 minutes for drill setup, 110 minutes for actual drilling, and 45 minutes to load and fire.

A Bucyrus-Erie hydromucker was adapted for use in the wet shaft. The mucker consists of a 3/8-yard clamshell bucket supported by tugger hoist and operated by two hydraulic rams, a hydraulic power unit, and the necessary hydraulic hoses. The hydraulic unit of the hydromucker is usually powered by a 15-hp., 440-v. electric motor; in this case it was replaced by a vane-type air motor to reduce the electrical hazard. In use, the power unit occupies one compartment of the three-compartment set (fig. 6), the regular cage-over-skip occupies the center compartment, and the clamshell operates in alternate outside compartments. Both sides of the skip have hinged panlike chutes to direct muck from the clamshell into the skip. The pans are lowered by a tugger hoist located in the framework of the skip and controlled by a remote four-way valve from the man cage. The pan not in use is locked in place, and both pans are closed and latched while hoisting is in progress. Mucking and hoisting of a round to the 1700 pocket was completed in 20 skip trips and required about 3 hours.

Standard shaft timber was carried to within 20 feet of the bottom. The bottom set was protected from fly rock by a steel battleship, which was lowered to serve as staging for installing the succeeding set of timber. Dividers were omitted from the lowest set to give the clamshell and tugger operators an unobstructed view of the bottom. Bearing sets were installed at 200-foot intervals.

Water control was a serious problem in the Sidney shaft. Originally, so-called self-priming electric pumps were tried, but these were unsatisfactory in that they failed to hold their prime and were inadequately insulated against excessive moisture. Two air-powered sump pumps in tandem were then used to pump from the bottom to a 150-gallon tank in the manway. A 20-hp. pump relayed the water to permanent pump stations located at 400-foot intervals in the shaft.

Ventilation was provided by two centrifugal exhaust fans installed at the 1700 shaft station and exhausting approximately 4,000 c.f.m. from the bottom through a 15-inch galvanized ventilation line. Approximately 40 minutes was required to clear the bottom of smoke.

The sinking crew consisted of four bottom men on each of two daily shifts.

SILVER MOUNTAIN MINE

Main Shaft

The Silver Mountain shaft was sunk by Hecla Mining Co. in cooperation with Bunker Hill Mining and Concentrating Co. and with the aid of the DMEA as a purely exploratory project to investigate at depth a wedge-shaped section of ground having abundant surface evidence of mineralization. The area that was investigated is bounded by three major faults—the Paymaster fault, the Deadman shear zone, and the National-Snowstorm fault. The last-named fault was host to ore bodies that produced more than $10,500,000 in copper from the Snowstorm mine prior to 1915. The other faults had practically no production but exhibited wide zones of hydrothermal alteration similar to those that overlie deep-seated ore bodies in several mines of the district.

Sinking the Silver Mountain shaft required the installation of a complete mine plant, including selection and preparation of a site, location of access roads, acquisition of equipment, and construction of the headframe, surface facilities, and shaft collar. Work on the surface started Apr. 1, 1955; shaft sinking started in February 1956 and was completed in December, in a total of 233.75 working days. The shaft contains three compartments, measures 9 by 18 feet in rock section, and extends to a depth of 2,083 feet.

Preliminary surface preparation and construction, including 1,604 feet of core drilling, required 11 months and cost slightly more than $70,000. The headframe was constructed of 12- by 12-inch timber resting on a reinforced-concrete foundation, which also served as capping for the shaft collar. The true collar, raised several feet above the surface and extending 8 feet to a water seal at bedrock, was constructed of reinforced concrete.

After the shaft collar was completed, the first several sets were mucked by hand until sufficient headroom was obtained to install the Riddell mucker that was used for the remaining footage.

The Silver Mountain shaft was sunk in soft-to-medium-hard slate and quartzite of the Wallace and St. Regis formations in which hand-held jackhammers functioned satisfactorily. A 27-hole bench round was drilled with two 65-pound machines to a depth of 7 feet in approximately 4 hours. Drill holes were collared with 2-1/2-inch steel bits and cased to solid ground with 2-inch pipe. The remaining depth was drilled with integral carbide chisel bits on 1-inch hexagonal steel. All holes were loaded to the collar with 45-percent semigelatin powder and detonated with regular-delay electric caps from a blasting circuit on the surface. The average full-shaft advance of 3.28 feet per round required 0.15 pound of powder per cubic foot.

A Riddell mucker working in conjunction with two 20-cubic-foot skips operating in balance permitted very rapid muck handling, a significant factor as the shaft deepened. Four men were required to complete the mucking cycle: One man to spot the clamshell, another to scale the walls, a third to operate the mucker, and the fourth to signal the hoist operator. As soon as the bench was cleared, the remaining muck was blown off with a blowpipe, and the bench was readied for drilling. Only enough muck was taken from the sump side to make room for the pump. About 3 man-hours per foot of advance was consumed in mucking, and the total mucking operation, from preparation to cleaning the bench for the succeeding round, required 2-1/2 hours. The Riddell mucker was usually located two or three sets above the bottom and was lowered as sets were added.

The shaft was timbered on 5.25-foot centers with standard Coeur d'Alene shaft sets alined with 150-foot plumb bobs in diagonal corners. The steel blasting set, used to protect the bottom timber from fly rock, was lowered to serve as staging for timbering. Timber was lowered in the skip in the order it was used and loosely assembled on the battleship. The center skip then hoisted the entire set into position to be tightened and blocked. Dividers were omitted below the mucker set and were added when the mucker was lowered.

Timber was carried within 10 to 15 feet of the bottom for the first 1,000 feet. Ground control became more difficult with depth, and it was necessary to timber as close to the bottom as possible. Rock bolts were installed to help counteract the heavy ground. Only two bearing sets were used, one at the collar and one at the 1000 level.

An air-powered, high-head centrifugal sump pump in the shaft bottom pumped to a relay sump in the manway. Additional sumps with two-stage, solenoid-controlled 220-volt motor pumps on the 500, 1000, and 1500 levels pumped to the surface.

About 10 minutes was required to clear blasting fumes from the bottom by using compressed air. Normal ventilation was with a 40-hp. exhaust fan in the headframe, exhausting approximately 10,000 c.f.m. through 24-inch ventilation pipe. An auxiliary 3-hp. axial-flow fan mounted in the shaft served to supplement the primary ventilation system and also was used at times in place of compressed air to clear the bottom after a blast. A four-man bottom crew and a hoistman were employed on each of three shifts per day. In addition, a topman and laborer worked the day shift only. The bottom crew worked on a contract basis of $55.00 per foot with time and a half for the 6th day. The topman and hoistmen received a bonus which amounted to 20 percent of the difference between day's pay and the contract bonus.

STAR MINE

The Star mine, at Burke, Idaho, lies between two famous mines, the Hecla and the Morning, both now abandoned. The Star was originally mined through an adit that surfaced near Mullan, Idaho. In 1921 it was acquired by Hecla Mining Co. and the Bunker Hill and Sullivan Mining Co. and was mined through the shaft of the adjoining Hecla mine.

In 1946-47, an existing four-compartment winze in the Star mine was extended to the 5200 level to develop a block of ore known to exist at that depth. In 1951-52, the winze was continued 785 feet to bottom on the 6300 level, 500 feet below sea level. During the same period, an 8,000-foot adit was driven to intersect a shaft raise in the Star mine. The Hecla shaft was then abandoned, and the new adit, the raise (which now became the Star shaft), and the Star winze became the principal means of access to the mine. The foregoing development was by the Sullivan Mining Co., which has since been dissolved. The mine is now owned by The Bunker Hill Co. and managed by Hecla Mining Co.

Since the winze was sunk in two periods by different methods, the projects will be discussed separately as the winze and winze extension. Both are four-compartment shafts 22.0 by 9.2 feet in rock section. In the interim between major sinking projects, the winze was advanced a total of 113 feet in several stages, for which no records are available. Country rock is hard Revett quartzite in beds 6 to 12 inches thick and varying from 50° to vertical in dip.

Star Winze

The Star winze was extended from the 4700 to 5222 levels in 1946 by hand mucking. Inasmuch as the winze was extended from an existing sump, no site preparation other than drainage and rehabilitation of the bottom was necessary. Ore pockets on the 4700 level, originally excavated for stoping operations, were adequate for waste storage. An auxiliary hoist was installed on the 4700 level for sinking. Waste was raised from there to the haulage level by the main hoist.

The bottom crew, consisting of four men on each of two shifts, used two 3-inch power-feed drifters mounted on a 3-inch pneumatic bar placed horizontally across the short axis of the shaft to drill out a bench round of 20 to 25 holes to a average depth of 4.6 feet. Holes were collared with 2-1/2-inch steel bits to a depth of 15 inches, cased with 2-inch pipe, and continued to depth with 1-1/8-inch round, hollow steel in 18-inch changes with four-wing steel bits. Holes were loaded to the collar with 40-percent gelatin dynamite and detonated with regular caps and safety fuse. Approximately 36 pounds of powder was consumed per foot of shaft.

Broken muck was loaded by hand into a 12-cubic-foot pan, which in turn was dumped into one of two 24-cubic-foot sinking buckets for hoisting in balance to waste pockets on the 4700 level. From 38 to 46 buckets was hoisted per round. Muck was relayed to the main haulage drift on the 4000 level by the main hoist and utilized as backfill elsewhere in the mine. The mucking-hoisting cycle averaged about 2.7 hours. Advance per round averaged 2.3 feet.

The shaft was timbered with standard Coeur d'Alene shaft sets carried as close to the bottom as possible to facilitate installation from the muck pile. A wooden blasting set of heavy logs protected the bottom timber while blasting. About 400 board feet of red fir and 8.7 man-hours for installation were required per foot of shaft.

Winze Extension

In the interim between 1947 and 1952, the winze was extended a total of 113 feet in several stages, for which no records are available. In 1952 and 1953, the second major shaft-sinking project was undertaken, and the winze was extended 965 feet to the 6300 level. The winze extension bore little resemblance to the earlier winze project, principally because of the difference in sinking methods.

The same type of drill and bench round was used, that is, two 3-inch power-feed-drifters mounted on a 3-inch air bar, but 34 rather than 20 to 25 holes were drilled per round in order to provide better fragmentation for the mechanical mucker. Even so, feet drilled and blasted per man-hour with the same number of men but with tungsten carbide rather than steel bits increased from 4.7 to 10.7, and advance per round increased from 2.3 to 3.1 feet. Electric-delay caps, used in the extension in place of fuse and caps but with the same type of powder, reduced powder consumption from 35.6 to 31.8 pounds per foot of advance.

The greatest difference between the two projects was the use of a Riddell mechanical mucker to sink the extension. While the actual time to load and hoist a round was reduced by about 27 percent, the use of a mechanical mucker increased efficiency throughout the sinking cycle.

The Riddell mucker was similar in construction and operation to others used in the district. The carriage was usually located two or three sets above the bottom and lowered when sets were added. Four men were used in the bottom during the mucking operation: One man to operate the mucker, another to signal the hoist operator, the third to position the clamshell bucket, and the fourth to scale the walls.

Muck was hoisted to waste pockets on the 4700 level by an auxiliary hoist and sinking bucket and then raised to the main haulage level by the main skip operating in balance. The sinking hoist was a 200-hp., 2,200-v., single-drum unit with a rope speed of 1,210 f.p.m.

Standard timber sets were carried as close to the bottom as feasible, usually 10 to 15 feet. A steel blasting set protected the bottom from flying rock and was later used as staging to install timber. Installation of dividers in the bottom sets was deferred to facilitate operation of the mucker.

Approximately 20 minutes was required to remove smoke and gas from the bottom. A 19-inch exhaust pipe carried about 30 feet above the bottom was powered by a nonreversing fan located at the 4700-level station. Sufficient airflow was present in the regular mine ventilation system on this level to dissipate the fumes rapidly.

An air-powered sump pump raised water from the bottom to a steel tank placed in the manway from 40 to 70 feet above the bottom. It was then relayed by a two-stage centrifugal motor pump to the mine pumping station on the 4000 level.

No. 2 Winze

In the mining system employed at the Star mine, development raises are driven in the ore zone to the level above to provide a means of bringing waste into the stope for backfill. On the lower levels, rock pressure is such that serious difficulties are encountered in raising the entire 200 feet between levels. Rock bursts and caving occur and the raises become excessively hazardous and frequently impossible to complete. With these conditions in mind it was felt that by sinking rather than raising, and by carrying timber close to the face, the heavy-ground condition might be controlled.

In 1957, the No. 2 winze (later called raise to conform with general terminology) was sunk from the 5500 level. Inasmuch as the winze was comparatively small in cross section (12.0 by 8.5 feet), and available headroom on the 5500 level was limited by an overlying gob-filled stope, the usual shaft-sinking equipment was not suitable. An adjustable steel A-frame was designed to fit in the available space, and a small opening was excavated to accomodate the hoist. A special bucket dump and a steel safety door were built and installed to permit dumping directly into waste cars on the 5500 level, since excavation of a head raise and dump pocket was not practical. After the experience in sinking the main winze, mechanical mucking was considered desirable. Commercial equipment for such a small rock section was not available, and it was necessary to design and fabricate an air-operated clamshell bucket in the company shops. Aside from the fabrication, installation, and use of special equipment, the winze was sunk in the same manner as the main shaft by a two-man crew working one shift per day.

A 24-hole bench round was drilled with two 55-pound hand-held sinker drills. Holes were collared with 2-1/2-inch steel bits, cased to about 15 inches with 2-inch pipe, and continued to 7 feet in three changes with 1-inch hexagonal steel and integral chisel bits. Holes were loaded with 40-percent gelatin dynamite and detonated with electric delay caps. Drilling and blasting required 8.5 man-hours per round and consumed 0.12 pound of explosive per cubic foot of rock broken.

The clamshell mucker designed for this project proved to be very satis factory. The bucket was patterned after similar clamshells that had been succesfully used in conjunction with the Riddell mucker on other projects. The jaws were powered with a 10-inch-diameter, double-acting air cylinder, which opened and closed the jaws with a chewing action that imparted a definite crowd effect. In operation it was suspended by cable from an air hoist placed on a platform in the manway several sets above the bottom. The bottom man positioned the clamshell by means of ropes attached to the jaws, and an operator controlled the actual digging. Two bites filled the bucket, and 60 buckets completed a round.

A 9.8-cubic-foot sinking bucket, lifted by a 2,000-pound, rope-pull, single-drum air hoist, was used with a company-designed and company-constructed air-powered bucket dump to empty directly into 50-cubic-foot waste cars on the 5500 level. A steel door operated by an air cylinder covered the hoisting compartment while dumping. The safety door and dump were operated by the hoistman but were controlled by a spring-actuated valve which permitted the dump to operate only when the door was closed.

Standard shaft timber sets on 5-foot centers were used. As the ore body dipped at 88°, the winze was 2° from vertical. The slight inclination made it possible to eliminate shaft guides and use slide boards on which the bucket rode on runners.

The sinking crew consisted of a bottom man, clamshell operator, hoistman, and part-time motorman.

SUNSHINE MINE

Jewell Shaft

Two of the four compartments of the main (Jewell) shaft of the Sunshine mine were extended 170 feet from the 3900 level to the 4100 level in 1956 to develop the western part of the Syndicate fault structure. The two-compartment extension is 13.8 by 9.4 feet in size. Sinking the 170-foot extension required 333 man-shifts for an average advance of 0.51 foot per man-shift. The mine is about 5-1/2 miles east of Kellogg.

Eighteen-hole bench rounds were drilled with two hand-held 55-pound sinker drills. Holes were collared to 18 inches with 2-1/2-inch steel bits, cased with 2-inch pipe, and continued to 5 feet with 7/8-inch hexagonal steel and integral four-wing tungsten carbide bits. About 22.7 pounds of 45-percent semigelatin dynamite detonated with regular-delay electric caps was required per foot of advance. Drilling, loading, and blasting required about 4.3 man-hours per foot.

Mucking required 5.9 man-hours per foot or 18.9 man-hours per round with a Riddell mucker. An auxiliary, single-drum air hoist was operated single stage to a waste pocket on the 3700 level to service the project. A 28-cubic-foot sinking bucket was used, and 2,016 buckets, or an average of 11.6 buckets per foot of advance, was hoisted.

Timber was carried within three to five sets of the bottom and placed two sets at a time on 6-foot centers. About 7.3 hours was required per set for installation, or about 3.2 man-hours per foot of advance.

TAMARACK MINE

Watson Shaft

The Tamarack mine, discovered in 1894 and owned since 1947 by Day Mines, Inc., is 5 miles northeast of Wallace. The three-compartment vertical Watson shaft provides access to the deeper sections of the mine and is collared underground on the 2400 level about 1,000 feet north of the main (Chesapeake) shaft. The latter is also an underground shaft and is collared 7,200 feet from the portal on the main (1200) haulage level. Two compartments of the Watson shaft were deepened 288 feet in 1952 to explore the productive Watson vein at greater depths. The vein, one of 13 metasomatic fissure veins which have been developed in the Tamarack mine, strikes N. 60° W. and dips 70° NE. The shaft was collared near the vein and bottomed (73 feet below the 3300 level) in the footwall 350 feet south of the vein.

The shaft was sunk by hand shoveling in 108 working days by two three-man crews working two shifts per day 6 days per week. Advance averaged 2.6 feet per round, which compares favorably with mechanically shoveled shafts.

Bench rounds of 22 to 25 holes per round were drilled to a depth of 5 feet with 2 55-pound hand-held sinker drills using 1-1/8-inch round steel in 3 18-inch changes and 4-wing 1-5/8-inch carbide-insert bits. Drill holes were loaded with 40-percent gelatin dynamite and detonated with 0 through 10 electric delay caps. Average time required for drilling and blasting one round was 204 minutes—36 minutes to set up and dismantle equipment, 120 minutes for actual drilling, and 48 minutes to load and blast. Powder consumption amounted to 19.2 pounds per foot of advance or 0.15 pounds per cubic foot of rock broken.

Rock broken by the shaft round was hand mucked into an 8-cubic-foot pan which was dumped by a small hoist into one of two 16-cubic-foot sinking buckets. Two pans were required to fill one bucket, and as one bucket was being filled the other was dumped. Approximately 42 buckets was hoisted per round. Mine operations above the 3000 level continued while shaft sinking was in progress; therefore, shaft waste was hoisted only to the 3000 level during the mucking cycle and was dumped on the station floor and slushed to a waste pocket to be hoisted the remaining distance to the 2400 level later. Mucking and hoisting averaged 26.6 man-hours per round.

The shaft measured 13.8 by 9.3 feet in rock section and was timbered on 5-foot centers with 10-inch preframed red fir. Wall plates were 11 feet 10 inches and end plates 7 feet 4 inches in length.

The shaft crew consisted of two bottom men and one hoistman on each shift. In addition, half of the time of one shift boss was charged to the project. Only the two bottom men were on contract, but the hoistman shared in the contract bonus. The contract price was $42.00 per foot of advance at the beginning of the project and was later raised to $45.00 per foot. Bottom labor was apportioned as 3.01 man-hours per foot for drilling and blasting, 4.21 man-hours for mucking, and 1.80 man-hours for timbering.

EXPLANATION OF TABLES

Information contained in the following tables was obtained for the most part from time-distribution records of the various companies and verified to some extent by spot observations and conversations with supervisory personnel and shaftmen. Data for individual mines are accurate and reliable from the point of view of individual accounting systems. However, accounting systems and method of apportionment of charges to various accounts varies from company to company. In general, shaft-bottom labor is easily separated from other

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mine labor, part-time or concurrent labor is more difficult to determine, and overhead costs may be apportioned empirically.

In some cases, such as an isolated exploration shaft, all costs of operation must be charged against the shaft. In other cases, normal operating overhead costs can be charged against several working places, and the shaft is charged only a proportionate part.

The above factors combine to prevent an accurate comparison of shaft-sinking costs. The following tables are presented for information only, with full knowledge that they are only generally indicative of the true costs.

TABLE 6. - General information

			Depth [1]			Size	Compartments			
Mine and shaft	Company	Year sunk	From, ft.	To, ft.	Distance, ft.	Timber section, ft. [2,3]	Purpose	Size, in.	Rock type	Remarks
Atlas Main shaft	Hecla Mining Co.	1952-53	860	2,521	1,661	7.2x16.0	Hoisting (2) Manway (1)	52x66	Strong, medium-hard argillaceous quartzite. St. Regis formation.	Existing inactive underground shaft rehabilitated and extended 1,661 ft. for exploration purposes. Collar 9,600 ft. from portal.
Crescent Main shaft	Bunker Hill Co.	1953-54	1,200	3,200	2,000	15.0x5.8	Hoisting (2) Manway (1)	48x54 52x54	Strong, hard argillaceous quartzite. St. Regis formation.	Existing underground shaft extended 2,000 ft. for exploration purposes. Collar 4,000 ft. from portal. No other mining in progress.
Hercules Main shaft	Day Mines, Inc.	1953	1,367	1,680	313	6.8x17.3	Hoisting (2) Manway (1)	56x62 56x62	Strong, hard quartzitic argillite. Prichard formation.	Existing underground shaft extended 313 ft. for exploration purposes. Collar 8,500 ft. from portal.
Hercules 444 winze	do.	1957	1,600	1,954	354	5.7x10.0 [4] 8.5x13.0	Hoisting (1) Manway (1)	46x48	Strong, medium-hard hornfels and vein material. Prichard formation.	Collared on 1600 level 3,000 ft. west of main shaft. Sunk 354 ft. for development purposes.
Lucky Friday No. 2 shaft	Lucky Friday Mining Co.	1956-57	2,456	3,150	694	7.2x17.8	Hoisting (2) Manway (1)	58x66 58x66	Strong, hard argillaceous quartzite. Revett formation.	Existing winze extended 694 ft. for development purposes. Concurrent with regular mining.
Page Main shaft	American Smelting and Refining Co.	1956-57	3,130	3,450	320	9.3x17.5	Hoisting (2) Manway (1)	58x66 58x66	Strong, medium-soft quartzite. Revett formation.	Existing 55° inclined surface shaft extended 320 ft. for development purposes. Concurrent with regular mining.
Sidney Main shaft	Sidney Mining Co.	1954-55	1,750	2,350	600	7.2x16.0	Hoisting (2) Manway (1)	60x68 40x68	Strong, hard, thin-bedded argillite. Prichard formation.	Existing underground shaft extended 600 ft. for exploration. Collar 2,300 ft. from portal.
Silver Mountain Main shaft	Hecla Mining Co.	1956	32	2,083	2,051	7.2x16.0	Hoisting (2) Manway (1)	52x66 52x66	Firm, soft to medium-hard, thin-bedded argillite, brecciated below 1080 level. Wallace formation.	New shaft collared on surface sunk to 2,083 ft. for exploration purposes.
Star Main winze	do.	1946-47	4,700	5,222	522	9.1x20.1	Hoisting (2) Manway (1) Service (1)	52x66 52x66 52x66	Strong, hard quartzite. Rock pressure present. Revett formation.	Existing underground winze collared on 4000 level deepened 522 ft. for development purposes. Concurrent with regular mining.
Star Winze extension	do.	1951-52	5,335	6,300	965.5	9.1x20.1	Hoisting (2) Manway (1) Service (1)	52x66 52x66 52x66	Strong, hard quartzite. Rock pressure present. Revett formation.	Above winze extended 965.5 ft. for development purposes. Concurrent with other mining activity.
Star No. 2 winze	do.	1957	5,500	5,659	159	6.5x9.0 [4] 8.5x12.0	Hoisting (1) Manway (1)	54x66 36x54	Weak, crushed vein material.	Small development winze sunk 159 ft. Inclined 2° from vertical.
Sunshine Jewell	Sunshine Mining Co.	1956	3,919	4,088	169.7	7.4x11.8 [4] 9.4x15.8	Hoisting (1) Manway (1)	54x56 54x66	Strong, medium-hard argillite and quartzite sheared in places. St. Regis formation.	Two compartments of existing four-compartment shaft deepened 169.7 ft. for development purposes. Concurrent with regular mining.
Tamarack Watson	Day Mines, Inc.	1952	3,085	3,373	287.5	7.3x11.8	Hoisting (1) Manway (1)	56x68 56x68	Strong, medium-hard thin-bedded argillite. Prichard formation.	Existing underground shaft deepened 287.5 ft. for development purposes.

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[1] In reference to mine base level.
[2] Outside timber.
[3] Rock section is one foot outside timber unless otherwise shown.
[4] Actual rock section.

TABLE 7. - Supplies and equipment

	Drilling								Blasting		Loading and hoisting				
	Drill				Rods		Bits		Explosives			Hoisting			
Mine and shaft	Type	No.	Size	Mount	Type	Size (in.)	Type 1/	Ft.	Type	Strength (percent)	Mucking Method	Method	Capacity (cu. ft.)	No.	Distance (ft.)
Atlas Main shaft	Drifter	2	3"	Air-bar	Hex.	1	4-wing detachable	(2)	Semi-gelatin	45	Mechanical (Riddell)	Skip	24	2	1,744
					do.	1	Integral chisel	-	Special gelatin	60					
Crescent Main shaft	do.	2	3"	do.	Round	1-1/8	4-wing detachable	(2)	Semi-gelatin	45	do.	Bucket - skip	21	2	750
Hercules Main shaft	Sinker	2	65-lb.	Hand-held	do.	1-1/8	do.	130	Special gelatin	40	Hand	Pan - bucket	8 16	1 2	332
Hercules 444 winze	do.	2	65-lb.	do.	do.	1-1/8	do.	125	do.	40	do.	Bucket	13	1	211
Lucky Friday No. 2 shaft	do.	2	55-lb.	do.	Hex.	7/8	Integral chisel	-	Semi-gelatin	45-60	Mechanical (Cryderman)	do.	30	2	427
Page Main shaft	do.	2	55-lb.	Air-leg Hand-held	do.	7/8	do.	-	Special gelatin	40	do.	Skip	45	1	270
Sidney Main shaft	Drifter	2	3"	Air-bar	do.	1	do.	-	do.	60	Mechanical (Hydromucker)	do.	36	1	450
Silver Mountain Main shaft	Sinker	2	65-lb.	Hand-held	do.	1	do.	-	Semi-gelatin	45	Mechanical (Riddell)	do.	30	2	1,060
Star Main winze	Drifter	2	3"	Air-bar	Round	1-1/8	4-wing steel detachable	1.6	Special gelatin	40	Hand	Pan - bucket	12 24	1 2	622
Star Winze extension	do.	2	3"	do.	do.	1-1/8	4-wing detachable	244	do.	40	Mechanical (Riddell)	Bucket	24	2	1,447
Star No. 2 winze	Sinker	2	55-lb.	Hand-held	Hex.	1	Integral chisel	-	do.	40	Mechanical (local design)	do.	10	1	83
Sunshine Jewell	do.	2	55-lb.	do.	do.	7/8	4-wing integral	-	Semi-gelatin	45	Mechanical (Riddell)	do.	28	1	130
Tamarack Watson	do.	2	55-lb.	do.	Round	1-1/8	4-wing detachable	(2)	Special gelatin	40	Hand	Pan - bucket	8 16	1 2	200

1/ All bits have tungsten carbide inserts unless shown otherwise.
2/ Not available.

TABLE 8. - Labor distribution

	Advance		Bottom crew 1/					Supporting labor 1/						
Mine and shaft	Ft.	Cu.ft.	Drill and blast	Mucking	Timbering	Other	Total	Hoisting	Rock disposal	Timber framing	Engineering and supervision	Other	Total	Total labor
Atlas, Main shaft														
Shift	2.1	344.4	9.92	7.60	6.08	8.40	32.00	8.0	6.40	4.00	2.64	30.40	51.44	83.44
Round	2.8	459.2	13.22	9.80	7.84	10.92	42.67	10.67	8.54	5.32	3.53	40.54	68.60	111.2
Foot advance		164	4.72	3.62	2.90	4.00	15.24	3.81	3.05	1.90	1.26	14.48	24.50	39.7
Cubic foot			.0287	.0221	.0177	.0244	.0930	.0232	.0186	.0116	.0077	.0883	.1493	.24
Crescent, Main shaft														
Shift	2.8	372.4	11.20	8.01	6.41	6.41	32.00	8.01	8.01	4.00	8.01	38.39	66.39	98.39
Round	3.1	412.3	12.40	8.87	7.10	7.10	35.43	8.87	8.87	4.43	8.87	42.50	73.50	108.93
Foot advance		133	4.00	2.86	2.29	2.29	11.43	2.86	2.86	1.43	2.86	13.71	23.71	35.1
Cubic foot			.0301	.0215	.0172	.0172	.0859	.0215	.0215	.0108	.0215	.1030	.1783	.2
Hercules, Main shaft														
Shift	1.1	188.1	4.00	6.40	4.00	9.60	24.00	8.00	2.72	1.44	3.20	15.90	31.36	55.36
Round	3.0	513.0	10.92	17.46	10.92	26.19	65.46	21.81	7.41	3.93	8.73	43.65	85.53	150.99
Foot advance		171	3.64	5.82	3.64	8.73	21.82	7.21	2.47	1.31	2.91	14.55	28.51	50.33
Cubic foot			.0213	.0340	.0213	.0511	.1276	.0425	.0144	.0077	.0170	.0845	.1667	.29
Hercules, 444 winze														
Shift	.93	103.2	2.72	6.40	2.24	4.64	16.00	8.00	3.36	1.68	4.64	8.80	26.48	42.48
Round	1.80	199.8	5.26	12.38	4.34	8.98	30.96	15.48	6.50	3.26	8.98	17.03	51.26	82.22
Foot advance		111	2.92	6.88	2.41	4.99	17.20	8.60	3.61	1.81	4.99	9.46	28.48	45.68
Cubic foot			.0263	.0620	.0217	.0450	.1550	.0775	.0325	.0163	.0450	.0852	.2565	.41
Lucky Friday, No. 2 shaft														
Shift	1.6	288.0	7.20	4.80	4.00	8.00	24.00	8.00	6.00	.32	2.96	8.96	26.24	50.24
Round	2.5	450.0	11.25	7.50	6.25	12.50	37.50	12.50	9.38	.50	4.63	14.00	41.01	78.51
Foot advance		180	4.50	3.00	2.50	5.00	15.00	5.00	3.75	.20	1.85	5.60	16.40	31.40
Cubic foot			.0250	.0167	.0139	.0278	.0833	.0278	.0208	.0011	.0103	.0311	.0911	.17
Page, Main shaft														
Shift	1.7	307.7	-	-	-						-	-	-	-
Round	3.3	597.3	-	-	-	NOT AVAILABLE					-	-	-	-
Foot advance		181	-	-	-						-	-	-	-
Cubic foot			-	-	-						-	-	-	-
Sidney, Main shaft														
Shift	1.7	278.8	8.00	8.00	5.60	10.40	32.00	5.60	4.00	4.00	8.00	30.40	52.00	84.00
Round	2.8	459.2	13.19	13.19	9.21	17.14	52.70	9.21	6.58	6.58	13.19	50.07	85.65	138.3
Foot advance		164	4.71	4.71	3.29	6.12	18.82	3.29	2.35	2.35	4.71	17.88	30.58	49.4
Cubic foot			.0287	.0287	.0201	.0373	.1148	.0201	.0143	.0143	.0287	.1054	.1865	.30
Silver Mountain, Main shaft														
Shift	2.9	475.6	9.05	8.73	7.28	6.96	32.00	8.00	2.00	6.00	8.47	13.60	38.09	70.0
Round	3.3	541.2	10.30	9.93	8.28	7.92	36.40	9.11	2.28	6.83	9.64	15.48	43.36	79.7
Foot advance		164	3.12	3.01	2.51	2.40	11.03	2.76	.69	2.07	2.92	4.69	13.14	24.1
Cubic foot			.0190	.0184	.0153	.0146	.0673	.0168	.0042	.0126	.0178	.0286	.0801	.1
Star, Main winze														
Shift	.83	166.0	7.84	9.76	7.20	7.20	32.00	8.00	(2)	2.00	.48	7.20	17.68	49.6
Round	2.3	460.0	21.74	27.05	19.94	19.94	88.67	22.17	(2)	5.54	1.33	19.94	48.98	137.6
Foot advance		200	9.45	11.76	8.67	8.67	38.55	9.64	(2)	2.41	.58	8.67	21.30	59.8
Cubic foot			.0473	.0588	.0434	.0434	.1928	.0482	(2)	.0121	.0029	.0434	.1065	.2
Star, Winze extension														
Shift	1.43	286.0	9.12	10.08	6.72	6.08	32.00	8.00	(2)	2.65	.40	4.00	15.05	47.0
Round	3.1	620.0	19.78	21.86	14.57	13.18	69.38	17.33	(2)	5.74	.87	8.68	32.62	101.9
Foot advance		200	6.38	7.05	4.70	4.25	22.38	5.59	(2)	1.85	.28	2.80	10.52	32.9
Cubic foot			.0319	.0352	.0235	.0213	.1119	.0279	(2)	.0093	.0014	.0140	.0526	.1
Star, No. 2 winze														
Shift	.96	97.9	2.40	5.60	3.20	4.80	16.00	8.00	(2)	4.80	.80	4.00	17.60	33.6
Round	3.4	346.8	8.50	19.82	11.32	17.00	56.68	28.32	(2)	17.00	2.83	14.18	62.33	119.0
Foot advance		102	2.50	5.83	3.33	5.00	16.67	8.33	(2)	5.00	.83	4.17	18.33	35.0
Cubic foot			.0245	.0572	.0326	.0490	.1634	.0817	(2)	.0490	.0082	.0409	.1798	.3

TABLE 8. - Labor distribution--Continued

Mine and shaft	Advance		Bottom crew 1/					Supporting labor 1/						Total labor
	Ft.	Cu.ft.	Drill and blast	Mucking	Timbering	Other	Total	Hoisting	Rock disposal	Timber framing	Engineering and supervision	Other	Total	
Sunshine, Jewell shaft														
Shift	1.18	175.8	-	-	-						-	-	-	-
Round	2.2	327.8	-	-	-	NOT AVAILABLE					-	-	-	-
Foot advance		149	-	-	-						-	-	-	-
Cubic foot			-	-	-						-	-	-	-
Tamarack, Watson shaft														
Shift	1.33	171.6	4.00	5.60	2.39	4.00	16.00	8.00	11.20	3.20	6.40	6.40	35.20	51.21
Round	2.6	335.4	7.83	10.95	4.68	7.83	31.28	15.65	21.89	6.27	12.51	12.51	68.83	100.01
Foot advance		129	3.01	4.21	1.80	3.01	12.03	6.02	8.42	2.41	4.81	4.81	26.47	38.50
Cubic foot			.0233	.0326	.0140	.0233	.0932	.0467	.0653	.0187	.0373	.0373	.2053	.2985
Average -														
Two-compartment shafts 3/														
Shift	1.07	124.2	3.02	6.03	2.69	4.63	16.36	8.19	4.29	3.28	3.79	6.58	26.13	42.49
Round	2.6	301.6	7.31	14.66	6.53	11.26	39.75	19.89	10.43	7.98	9.20	15.99	63.49	103.24
Foot advance		116	2.81	5.64	2.51	4.33	15.29	7.65	4.01	3.07	3.54	6.15	24.42	39.71
Cubic foot			.0242	.0486	.0216	.0373	.1317	.0659	.0346	.0265	.0305	.0530	.2105	.3423
Three-compartment shafts 4/														
Shift	2.03	324.6	8.36	7.80	5.81	9.66	31.63	8.47	5.14	3.13	5.58	23.99	46.31	77.94
Round	2.92	467.2	12.03	11.21	8.35	13.90	45.49	12.18	7.39	4.50	8.03	34.51	66.61	112.10
Foot advance		160	4.12	3.84	2.86	4.76	15.58	4.17	2.53	1.54	2.75	11.82	22.81	38.39
Cubic foot			.0258	.0240	.0179	.0298	.0975	.0261	.0158	.0096	.0172	.0739	.1426	.2401
Four-compartment shafts 5/														
Shift	1.13	226.0	8.95	10.63	7.56	7.30	34.44	8.61	-	2.41	.49	6.49	18.00	52.43
Round	2.7	540.0	21.38	25.41	18.06	17.44	82.28	20.57	-	5.75	1.16	15.50	42.98	125.26
Foot advance		200	7.92	9.41	6.69	6.46	30.48	7.62	-	2.13	.43	5.74	15.92	46.40
Cubic foot			.0396	.0471	.0335	.0323	.1524	.0381	-	.0107	.0022	.0287	.0797	.2321
Average -														
All shafts 6/														
Shift	1.61	251.2	7.16	8.60	5.55	7.97	29.28	9.24	5.47	3.33	4.11	14.76	36.91	66.20
Round	2.79	435.2	12.42	14.90	9.63	13.81	50.76	16.01	9.49	5.78	7.11	25.58	63.97	114.72
Foot advance		156	4.45	5.34	3.45	4.95	18.19	5.74	3.40	2.07	2.55	9.17	22.93	41.12
Cubic foot			.0285	.0342	.0221	.0317	.1166	.0368	.0218	.0133	.0163	.0588	.1470	.2636

1/ **Man-hours per unit shown.**
2/ Used for backfill - **no charge to shaft.**
3/ Three shafts **represented.**
4/ Six shafts represented.
5/ Two shafts represented.
6/ Eleven shafts represented.

TABLE 9. - Summary of performance

			Feet drilled and blasted per			Blasting Explosives			Loading		Hoisting		Timbering	
Mine and shaft	Holes per round	Depth	round	ft.adv.	mhr.	lbs./ ft.adv.	lbs./ cu.ft.	cu.ft. /lb.	mhrs./rd.	cu.ft./ mhr.	mhrs./rd.	cu.ft. /mhr.	mhrs./set	mhrs./ ft.adv.
Atlas Main shaft	24-30	5.6	151.2	54.0	11.44	37.0	0.2256	4.43	9.80	46.86	10.67	43.04	15.2	2.90
Crescent Main shaft	30	6.2	186.0	60.0	15.00	32.3	.2429	4.12	8.87	46.48	8.87	46.48	12.6	2.29
Hercules Main shaft	30	6.0	180.0	60.0	16.48	37.2	.2175	4.60	17.46	29.38	21.81	23.52	18.2	3.64
Hercules 444 winze	18	3.6	64.8	36.0	12.33	32.5	.2928	3.42	12.38	16.14	15.48	12.91	12.1	2.41
Lucky Friday No. 2 shaft	25-30	5.0	137.5	55.0	12.22	28.9	.1606	6.23	7.50	60.0	12.50	36.00	14.5	2.50
Page Main shaft	20	6.6	132.0	40.0	(1)	20.0	.1111	9.05	(1)	(1)	(1)	(1)	(1)	(1)
Sidney Main shaft	36	5.6	201.6	72.0	15.29	41.2	.2512	3.98	13.19	34.81	9.21	49.86	17.4	3.29
Silver Mountain Main shaft	27	6.6	180.9	54.8	17.56	23.8	.1451	6.89	9.93	54.50	9.11	59.41	13.2	2.51
Star Main winze	20-25	4.6	103.0	44.8	4.74	35.6	.1780	5.62	27.05	17.01	22.17	20.75	45.5	8.67
Star Winze extension	34	6.1	212.0	68.4	10.72	31.8	.1590	6.29	21.86	28.36	17.33	35.78	24.7	4.70
Star No. 2 winze	24	6.8	163.2	48.0	19.20	12.3	.1206	8.29	19.82	17.50	28.32	12.25	16.7	3.33
Sunshine Jewell	18	4.4	79.2	36.0	(1)	22.7	.1523	6.65	(1)	(1)	(1)	(1)	(1)	(1)
Tamarack Watson	21	5.2	109.2	42.0	13.95	19.2	.1488	6.72	10.95	30.63	15.65	21.43	9.0	1.80
Average:														
Two-compartment shafts 2/	20.3	5.0	104.1	40.5	6/ 15.16	21.7	.1786	6.27	6/ 14.38	6/ 21.42	6/ 19.89	6/ 15.53	6/ 12.6	6/ 2.51
Three-compartment shafts 3/	27.9	5.9	167.0	56.5	7/ 14.67	31.5	.1934	5.61	7/ 11.13	7/ 45.34	7/ 12.18	7/ 43.05	7/ 15.2	7/ 2.86
Four-compartment shafts 4/	28.2	5.4	157.5	56.6	7.73	33.7	.1685	5.96	25.46	23.69	20.57	28.27	35.1	6.69
All shafts 5/	25.5	5.6	146.2	51.6	8/ 13.54	28.8	.1850	5.87	8/ 14.44	8/ 29.79	8/ 16.01	8/ 32.86	8/ 18.1	8/ 3.45

1/ Not available.
2/ Four shafts represented except as noted.
3/ Seven shafts represented except as noted.
4/ Two shafts represented.
5/ Thirteen shafts represented.
6/ Three shafts represented.
7/ Six shafts represented.
8/ Eleven shafts represented.

TABLE 10. - Summary of direct costs 1/

Mine and shaft	Labor and supervision				Supplies						
	Bottom	Support	Other 2/	Total	Steel, bits, air, etc.	Explosives	Timber	Power	Other	Total	Total
Atlas - Main shaft	37.7	28.7	3.6	70.0	2.4	4.0	8.5	2.1	13.0	30.0	100.0
Crescent - Main shaft	37.9	28.7	4.5	71.1	3.3	4.7	7.4	2.1	11.4	28.9	100.0
Hercules - Main shaft	41.2	28.3	2.5	72.0	2.6	4.1	9.0	3.7	8.6	28.0	100.0
Hercules - 444 winze	35.0	32.2	11.0	78.2	5.7	4.6	4.8	4.2	2.5	21.8	100.0
Lucky Friday - No. 2 shaft	-	-	-	-	NOT AVAILABLE		-	-	-	-	-
Page - Main shaft	-	-	-	-	NOT AVAILABLE		-	-	-	-	-
Sydney - Main shaft	35.3	28.6	4.5	68.4	2.4	4.8	6.7	2.1	15.6	31.6	100.0
Silver Mountain - Main shaft	40.9	17.7	2.4	61.0	1.6	4.1	12.1	1.3	19.9	39.0	100.0
Star - Winze	49.3	17.7	7.3	74.3	2.7	3.2	10.9	1.1	7.8	25.7	100.0
Star - Winze extension	44.3	12.5	6.0	62.8	2.4	4.1	10.5	1.2	19.0	37.2	100.0
Star - No. 2 winze	48.0	15.2	8.3	71.5	2.8	2.9	14.6	1.3	6.9	28.5	100.0
Sunshine - Jewell	-	-	-	-	NOT AVAILABLE		-	-	-	-	-
Tamarack - Watson	31.1	33.7	4.0	68.8	4.9	4.1	11.4	2.1	8.7	31.2	100.0
Average distribution - All shafts 3/	41.1	23.1	5.6	69.8	3.0	4.0	9.5	2.0	11.7	30.2	100.0
Average actual cost - All shafts 3/											
Per man-hour	$ 4.37	$ 2.14	$ .27	$ 6.78	-	-	-	-	-	-	$ 6.78
Per foot drilled	-	-	-	-	$ .12	$ .15	-	-	-	-	-
Per cubic foot	$ .51	$ .30	$ .07	$ .88	$ .04	$ .05	$ .12	$ .03	$ .14	$ .38	$ 1.26
Per linear foot	$79.93	$44.92	$10.98	$135.83	$ 5.83	$7.84	$18.42	$3.93	$22.73	$58.75	$194.58

1/ In percent of total

2/ Undifferentiated labor expense.

3/ Ten shafts represented.

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